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AERO/SPACE ENGINEERING

REVIEW OF CURRENT AND FUTURE TRENDS IN AIRCRAFT • MISSILES • ROCKETS • SATELLITES • SPACECRAFT

Mass Transfer Cooling (cover illustration) • Soviet Turbojets & Ramjets • A New Instrument for Space • Ground Effect Vehicles • Engine Trouble Shooting in Flight • More on the Laws of Gravitation

The Anglo-American Conferences—*An Editorial*. . . p. 27

OCTOBER / 1959

Three generations of ARMA computers:
THE PRESENT GENERATION

6,000
continuous hours of higher mathematics . . . without an error

The thinking apparatus of the guidance system of the **ATLAS ICBM**—ARMA's airborne digital computer—has now completed 6,000 hours of continuous laboratory operation without one catastrophic or transient error.

Fully transistorized, with no moving parts, this remarkable ARMA computer can be relied upon for dependable performance when the **ATLAS** becomes the nation's major deterrent weapon.

Two further generations of ARMA computers will be applicable to even more sophisticated uses. ARMA's advancement of the state of the art has made possible computers—soon forthcoming—that will surpass the present computer's reliability at a small fraction of its weight.

ARMA research and development has made the digital computer truly airborne. ARMA, Garden City, N. Y., a division of American Bosch Arma Corporation . . . the future is our business.

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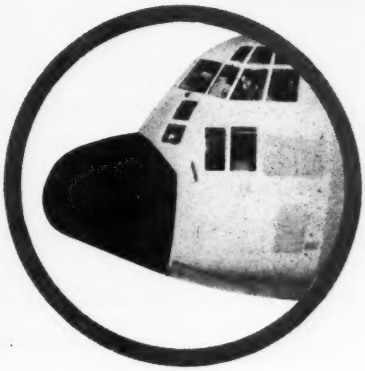
RECOGNIZE THESE

three famous noses?



Clue: All are structural plastic radomes built by Goodyear Aircraft

THESE NOSES MAKE NEWS, for they belong to aircraft with vast capabilities—the Boeing B-52G, the Convair B-58 and the Lockheed C-130 (A and B). Strikingly different in shape and in the manufacturing methods they require, the nose radomes shown here are alike in several key ways. All are built to demanding specifications by Goodyear Aircraft Corporation. All provide exceptional thermal, structural and electrical properties.

THE SNUB-NOSED B-52G RADOME, employing a honeycomb-sandwich construction, is one of the largest sandwich-type radomes ever designed for use on a high-speed aircraft.

THE NEEDLE-NOSED B-58 RADOME, a solid laminate made of high-temperature-resistant resin, houses special equipment calling for one of the most dimensionally precise radomes ever fabricated.

THE LOW-SLUNG C-130 (A and B) RADOME, a cored deicer, is one of the first successful *ducted* radomes ever built.

AS A FABRICATOR, Goodyear Aircraft has the unique capability of manufacturing the entire plastic radome assembly, including metal attachment parts. Goodyear Aircraft also has extensive testing facilities. The result: radomes of remarkable strength which approach complete electromagnetic transparency.

THESE ADVANCED METHODS AND MATERIALS stem from Goodyear Aircraft's vast experience with all types and sizes of radomes—from small aircraft radomes to huge ground radomes (the largest: 140-foot diameter). Can this experience solve a problem for you? WRITE—for full information—to: Goodyear Aircraft Corporation, Dept. 916FJ, Akron 15, Ohio.

AIRBORNE RADOMES—
ONE OF THE PRIME CAPABILITIES OF

GOODYEAR AIRCRAFT

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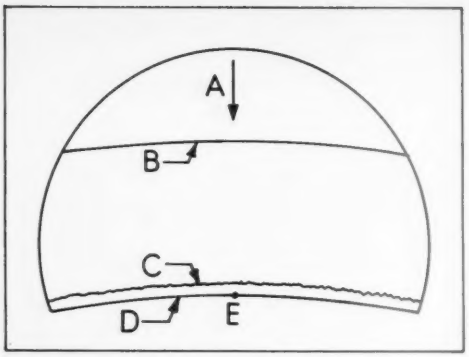

On our cover

The stagnation region of a hemispherical porous nose—focal point of the heat-transfer problem in hypersonic nose cone design—is revealed in this unusual color microschlieren photo provided by C. J. Scott of the University of Minnesota Rosemount Aeronautical Laboratories. Appearing exclusively in Aero/Space Engineering, it illustrates the leading article in this issue on "Some Experimental Techniques in Mass Transfer Cooling," by Bernard M. Leadon, AFIAS, of Convair's Scientific Research Laboratory. The line drawing at left, based on the photo, shows: Arrow A, Mach 5 flow direction; B, shock; C, helium layer; D, porous surface of hemispherical model; and E, stagnation point. The photo was obtained in the course of a research project sponsored by the Air Force Office of Scientific Research.

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"The prestige magazine of the Aerospace Industry"

AERO/SPACE ENGINEERING

VOLUME 18 / NUMBER 10 October 1959

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LETTERS to the Editor

For the Inquiring Mind

■ I would like to reply to "Finds Letter 'Nonsense' " and "Weightlessness Premise Wrong?" published in *A/SE*'s "Letters to the Editor" feature last month.

Regarding the Dzung letter: One of the few things I am absolutely sure of is that there are many problems in this universe which cannot now, or ever, be completely solved. The reason is simple—they are beyond human comprehension.

I feel quite safe in saying that in the 50 years I have belonged to the IAS more scientific progress has been achieved than in all prior recorded history.

Therefore every intelligent person has not only the right, but should make it his duty, to examine all of the ancient theories which were handed down to us to be sure they conform to our present knowledge, and wherever possible bring them up to date so they do not interfere with future progress.

New ideas are nearly always controversial. If they followed the path of popular thinking, they would have been expressed many times before.

I am sorry that Mr. Dzung took such a negative stand in his letter; a constructive approach would have made more sense.

✦ ✦ ✦

I have forwarded the following to Mr. Frank L. Wright:

"In my letter in the July issue of *A/SE* I meant to imply that the forces used to operate the ordinary inertial guidance system depended on weight and motion. You said no, it was mass. You then said 'Take Newton's Formula (Force equals Mass times Acceleration) and substitute Weight for Mass to get the correct answer.' The formula now reads: Force equals Weight times Acceleration. To me, this surely means weight and motion, as I stated in the first place.

"As for why particles leave a strong gravitational force for a weaker one—via escape velocity? You will surely admit that the escape velocity from a gravitational force supposedly 27 times that of the Earth would be a formidable one. At 2,000,000 deg. temperature, the gases could leave the Sun quite rapidly, but by the time they expanded enough to cool down to 1,000 deg.—around which some of the elements shown in spectrogram would take to solidify—this should result in a radial velocity of a rather low order, and I cannot imagine any force there which would boost these slow-moving particles to escape velocity speeds."

Frederick Charavay, AFIAS
Piqua, Ohio

Welcomes "Food for Thought"

■ "Isaac Newton Wrong?" (in the July letters) certainly does elicit comments, and here are mine.

As Mr. Charavay says, the only *measurable* force acting on our earthly bodies is that of the Earth's gravity itself. This does not mean that it is the *only* gravitational force acting on them. Newton should not be held accountable for the fact that, three centuries later, our instruments are not yet sufficiently refined for such delicate measurements.

As to the meteoritic dust that daily pelts the Earth, we have no proof that it comes from the Sun, but even the particles that do leave the Sun could be impelled by convection or by the very atomic forces which, Mr. Charavay says, make gravitational forces "insignificant and puny." Indeed, if convective forces on Earth can make huge volumes of liquid and gas rise many miles, then convection alone could account for the escape of particles (besides photons) that leave the Sun, considering the explosive temperatures involved.

I believe, as does Mr. Charavay, that tides are strongly influenced by expansive and contractile forces, although I believe these forces basically thermal in origin.

Mr. Charavay's remarks on the impossibility of navigating while in a state of weightlessness—i.e., that "all forms of inertia, acceleration, or centrifugal force depend on *weight* and motion"—are strongly debatable.

The universal laws of motion and inertia proposed by Newton clearly defined weight as a purely circumstantial quality, and *mass* as the invariable property of a body which relates an applied force to a resultant acceleration. Weight is merely the manifestation of a given gravitational field on a given mass.

As for the problem of heat dissipation in regard to space navigation—I do not doubt that by the time we are able to contemplate this adventure our technology will have solved the problem through the use of engines that will develop little heat, or even by converting waste heat into light, which is easily radiated.

The problem of keeping an "unstable" body on a given course through the use of many strategically located jets is, in my opinion, not the most formidable one facing the spaceship designers. After all (and here I again invoke Newton with, no doubt, the concurrence of most astronomers), a *weightless, frictionless* mass on a given trajectory should follow it in a most *stable* manner, without any need for correction until, of course, a new velocity is desired.

Mr. Charavay's letter was especially interesting to me because it gives food for thought. Furthermore, I admire his stand, even though I disagree with him.

Juan Todaro, TMIAS
Cuba Tecnica Industrial, S.A.
Havana, Cuba

Finds Engineer Species "Revolting"

■ As limited as my own experience and observation ability may be, I have noticed that there exists among our engineers an "I don't like it" type.

We are in a state of technological racing right now and probably will be for years to come. The race with the Communist world is a relay race, and the "I don't like it" engineer is not only a slow member, but often a deterrent.

His facets are many, but the underlying thoughts are ever present. As we all know, an aircraft or missile production drawing is subject to many pairs of eyes for approval. It is very easy to criticize someone else's work, but often it is very difficult to offer a better engineering suggestion.

The type of man I would like to describe here will unroll a tracing, and in a very short time pass judgment on its merits. The verdict is: "I don't like it." When questioned for alternate solutions, he usually has none at all, or has one that you have previously proved by the laws of physics and mathematics to be inadequate.

It is not uncommon that this man will hesitate to wield a slip-stick, or dig out a book to look up something, or plug some numbers in a formula. Preparing a scale drawing with a straight edge, compass, and sharp pencil is out of the question for him. It is also a common occurrence that these same fellows do not like their desks, working area, boss, management, or even the city and state in which they live. These men, as far as I can see, are in the same boat with us pulling in the opposite direction.

These fellows like the expression "rugged individualist." I have the utmost respect for the man who will think with unclouded perseverance, and one who will "stick to his guns" when he has evidence enough to feel he is correct in his calculations. The particular species of "I don't" individualist is to me, however, quite revolting.

It may seem cruel, but I think that these men must either be rehabilitated or rendered harmless. It is indeed fortunate that this type rarely occupies high places. It is quite logical that this attitude can scarcely begin to get a job done.

I can't help but think that this subject is very important, even from a national defense posture viewpoint. Beware of these men, and help them when you can.

Howard W. Smith
Structures Engineer
Boeing Airplane Company

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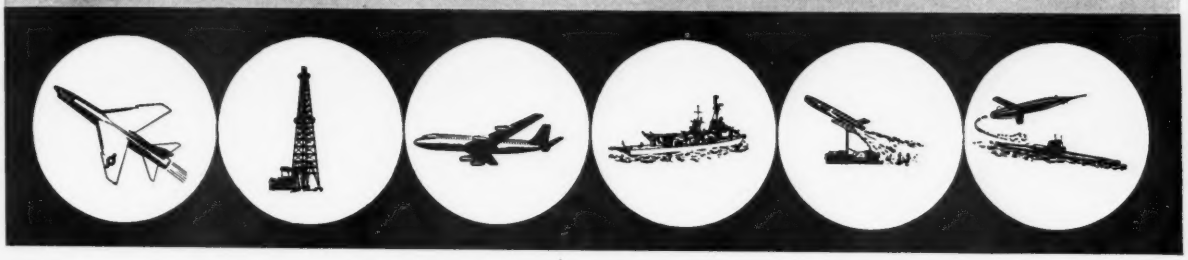
SERVO-SYSTEMS OF FORCE CONTROL



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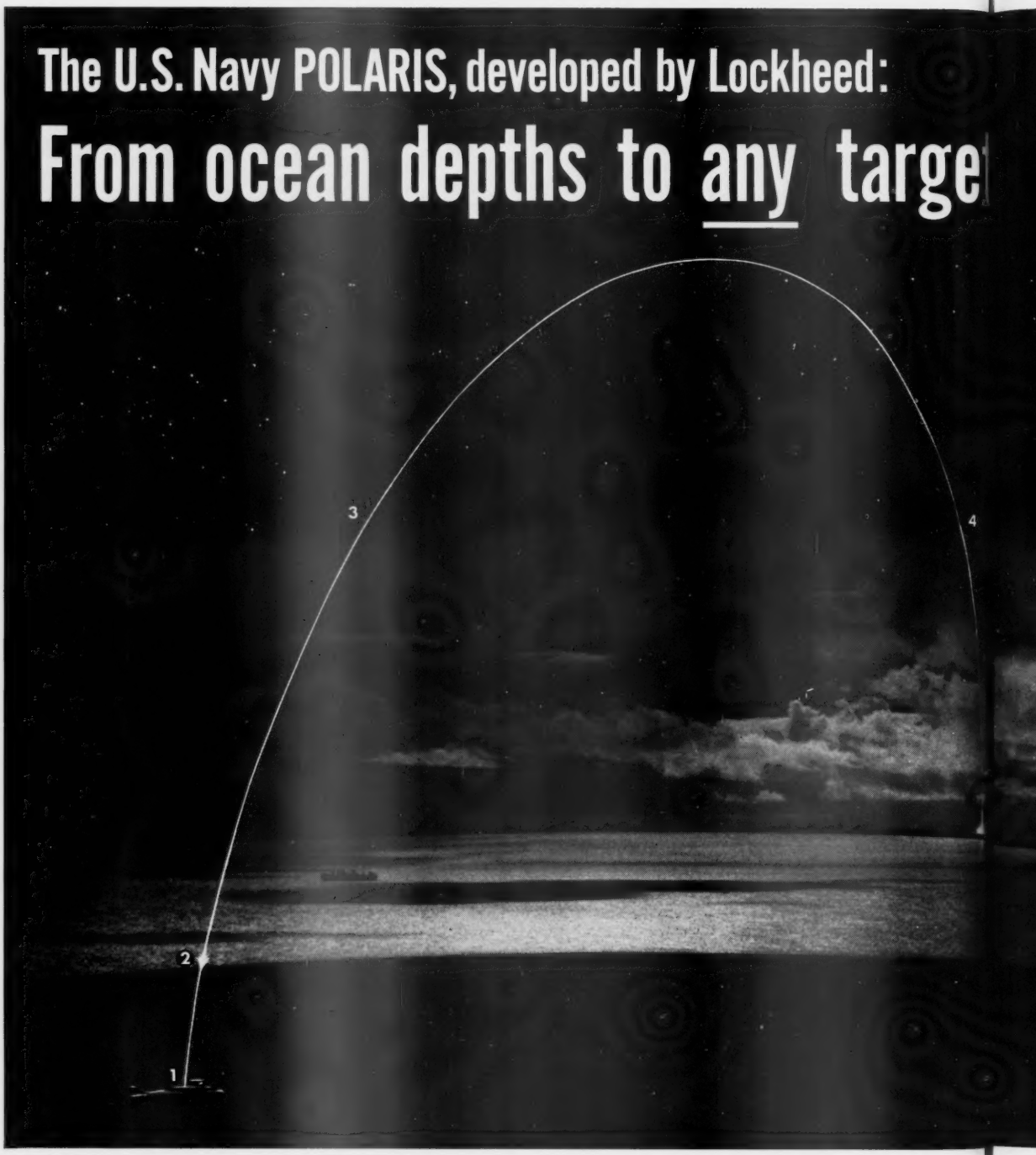
The U.S. Navy POLARIS, developed by Lockheed:

From ocean depths to any targe



Navy's hidden nuclear submarine (1) launches a solid-propellant POLARIS missile, which erupts from the depths (2), rockets its way in space (3). Plunging earthward minutes later, the warhead of the POLARIS re-enters earth's atmosphere (4) and destroys its target (5

America can breathe easier next year when the Lockheed-developed POLARIS missile goes to sea aboard the Navy's nuclear-powered submarines—far ahead of original schedule. For every significant military target will be within its ultimate range of 1500 nautical miles.

To be an effective deterrent to aggression, a weapon system must be safe from surprise, ready to strike back after any attack. The Navy's POLARIS submarines will be immune to detection as they prowl submerged for weeks at a time. And they'll move the bulls-eye of enemy attack from our soil to the trackless depths of the sea.

Lockheed's Missiles and Space Division is POLARI Missile System manager and prime contractor – leader o an industrial team that includes Aerojet-General, Gener Electric, Westinghouse, and hundreds of other contracto and suppliers, large and small. Close cooperation has brough the POLARIS from blueprint to hardware in record time.

This new combination of nuclear submarine and POLAR missile will round out the nation's arsenal and give us th flexibility we need for adequate defense.

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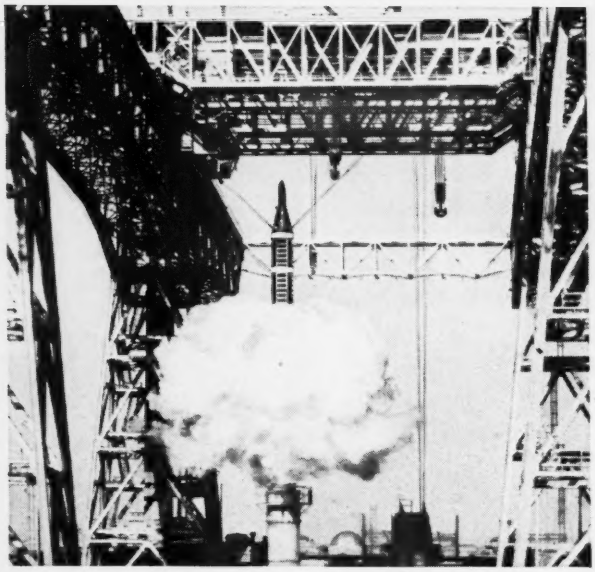
POLARIS is much smaller than other U.S. ballistic missiles of the same range, thanks to new miniaturization techniques developed by Lockheed scientists. This permits each nuclear submarine to carry 16 missiles.



"Operation Sky-Catch" is apt name for this huge overhead assembly. It catches POLARIS test vehicles in mid-air after test launchings. This prevents damage to components and gives more accurate instrument readings, thus saving time and speeding development. Tests are conducted jointly by U. S. Navy, Westinghouse, and Lockheed.

4,000-acre test base in the Santa Cruz Mountains of California is where Lockheed's Missiles and Space Division puts completed POLARIS missiles through simulated flights that prove the propulsion and guidance systems before actual flights of development missiles.

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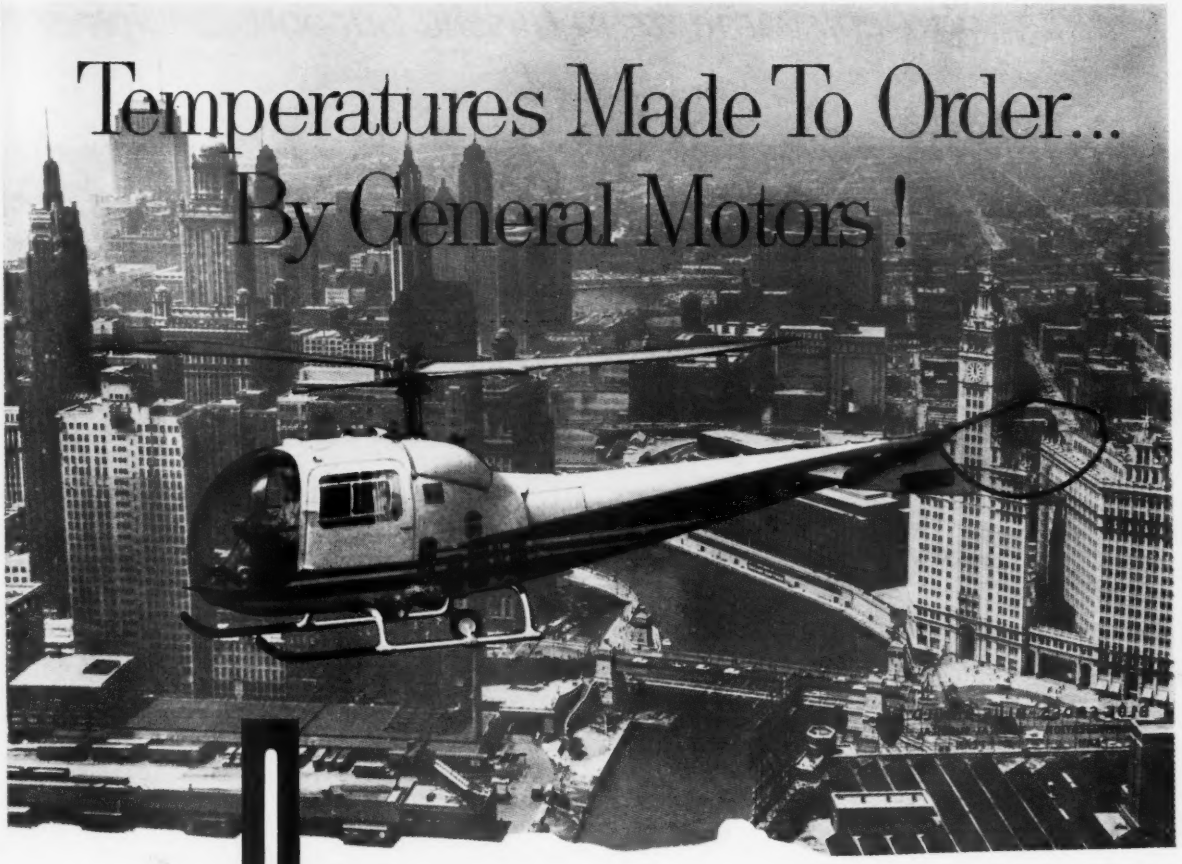

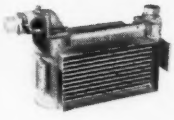

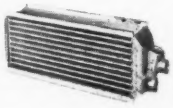

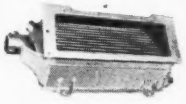

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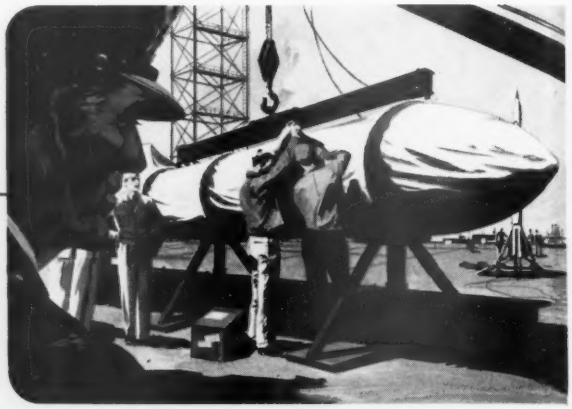
VEHICULAR EQUIPMENT . . . has been designed and developed having greater stamina and of much lighter weight. Specially designed prototype units were tested on rough terrain under the severest operating conditions. From these tests, significant design data resulted.



GROUND HANDLING EQUIPMENT . . . for servicing missiles and readying them for launching has been designed, developed and tested. However, a continuing program is in process at the Jet Propulsion Laboratory to further the state of the art in this important field.

MOBILE MISSILE SYSTEMS . . . were designed, developed and tested for use in transporting and servicing missiles. A tractor-trailer with launching pad in one complete unit was developed. Other equipment for loading and transporting missiles via air, land or sea has been developed.

GROUND SUPPORT EQUIPMENT . . . is developed to operate under conditions of rain, snow, ice, and heat. Mud and desert sand also create difficult environmental problems. Objectives are ease of operation and handling permitting the missile to be readily unloaded from airplanes, or landing craft and quickly positioned for firing.

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Throughout the construction of this re-entry vehicle shield, B. F. Goodrich maintains constant quality control of resin content and residual volatiles. Modern radiological facilities are used for final checking.

The fabrication and curing of such huge void-free parts illustrates the advances made by B. F. Goodrich in producing high-temperature, reinforced plastic products. So if you're up in the air and want down-to-earth answers on plastic laminate constructions, contact *B. F. Goodrich Aviation Products, a division of The B. F. Goodrich Company, Dept. AS-109, Akron, Ohio.*

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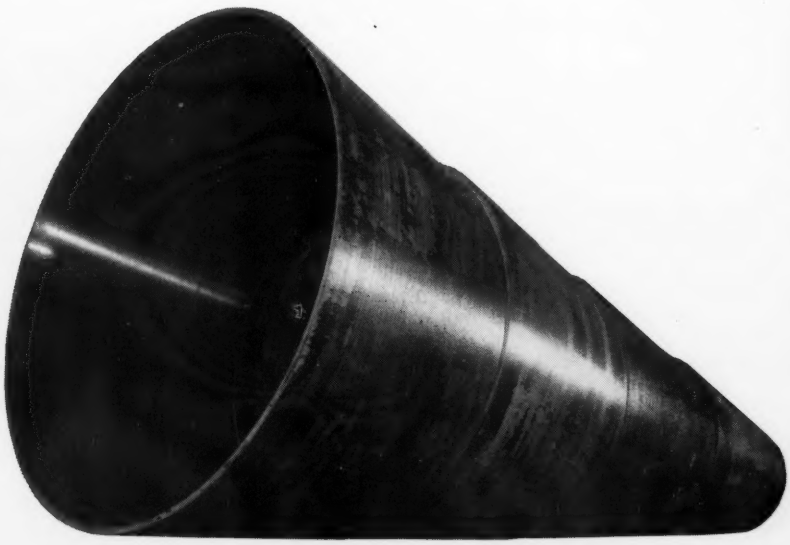

Jewels by Janitrol

If you are concerned with utilization, distribution, and control of high temperature, high pressure air for canopy seal, tank pressurization, fuel transfer, or any other interesting aircraft or missile application, this picture will interest you.

It shows an important facet of Janitrol's capabilities in the design and production of precision valves whose refinements and tolerances call for a jeweler's approach. The large family of Janitrol valves offers convincing evidence of our exceptional problem solving abilities in a field where reliability requirements are constantly being raised.

A complete picture of our capabilities is presented in a new brochure "Janitrol Resources." For your copy ask your nearest Janitrol engineering representative, or write: Janitrol Aircraft Division, Surface Combustion Corporation, Columbus 4, Ohio, BRoadway 6-3561. Also: Ft. Worth, WAlnut 6-3386; Hollywood, HOllywood 3-6861; Washington, D. C., OLiver 4-2171; Philadelphia, MIdway 2-6342.

pneumatic controls • duct couplings and supports • heat exchangers • combustion equipment for aircraft, missiles, ground support

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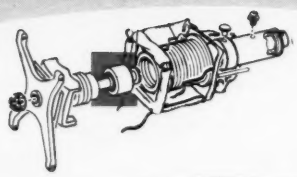
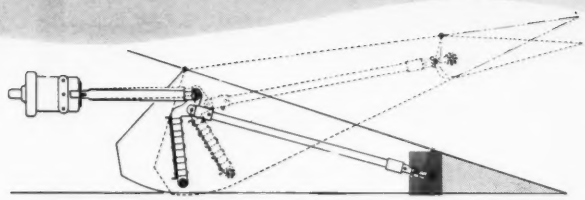
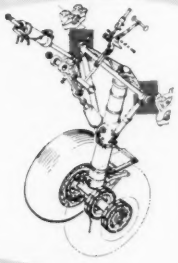
SHAFER® BEARINGS CARRY THE LOAD



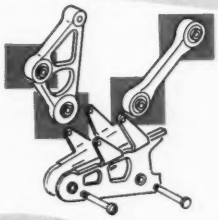
Elevator flight controls



Aileron trim and servo tab control system

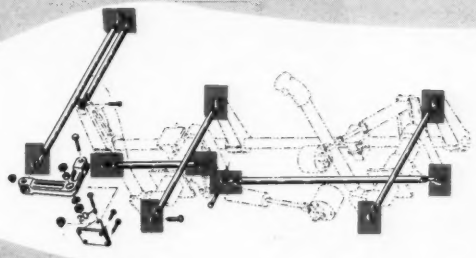


Main landing gear fulcrum and linkage

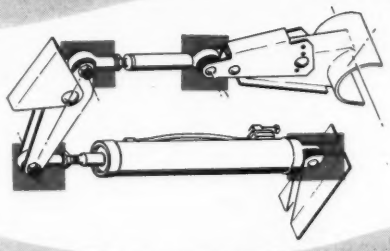


Wing flap hinge and linkage

Aileron hinge



Helicopter flight control group



Hydraulic actuator linkage

Helicopter blade pitch control link

Wherever design criteria call for greatest load-carrying capacity…smallest envelope dimensions and weight…Shafer Self-Aligning Anti-friction Bearings are specified today!
Shafer Bearing Division, CHAIN Belt Company, Downers Grove, Ill.

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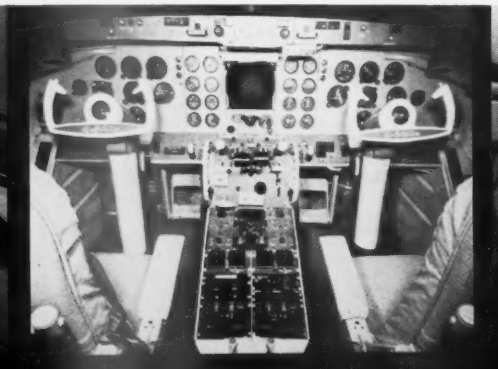
CHAIN BELT COMPANY

YOU ARE INVITED to inspect the airplane at one of the following distributors: Atlantic Aviation, Wilmington, Delaware; Southwest Airmotive, Dallas, Texas; Pacific Airmotive, Burbank, California; and Timmins Aviation, Montreal, Canada.



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THE INSIDE STORY ABOUT AMERICA'S NO. 1 BUSINESS AIRCRAFT— THE GRUMMAN GULFSTREAM

GULFSTREAM—by Grumman.....POWER—by Rolls-Royce.
INTERIOR—by the purchaser!

The pictures show how one leading corporation has "fitted out" its Gulfstream. The point is that the Gulfstream's basic configuration enables each corporation-owner to choose the interior layout, decor and equipment that individualize the aircraft to the company's precise needs and tastes. There is no "re-doing" airplanes originally designed for other purposes.

The Gulfstream has been conceived by Grumman expressly for corporate use. It uniquely combines performance, utility, reliability and safety to make it America's No. 1 Business Aircraft—and, therefore, the logical first choice of leading corporations. It carries 10-12 passengers.

Powered by two Rolls-Royce prop-jet engines, the Gulfstream cruises at 357 mph and has a range of 2600 miles plus reserve. Pressurization at 25,000 feet provides a comfortable air-conditioned cabin altitude of 5500 feet—permitting operation above the weather and traffic. The Gulfstream's ability to get in and out of smaller airports—those with runways of approximately 4000 feet—substantially increases its utility and scope of operations.

F.A.A. certified Gulfstreams are now being delivered to leading corporations through our distributors.

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AIRCRAFT ENGINEERING CORPORATION

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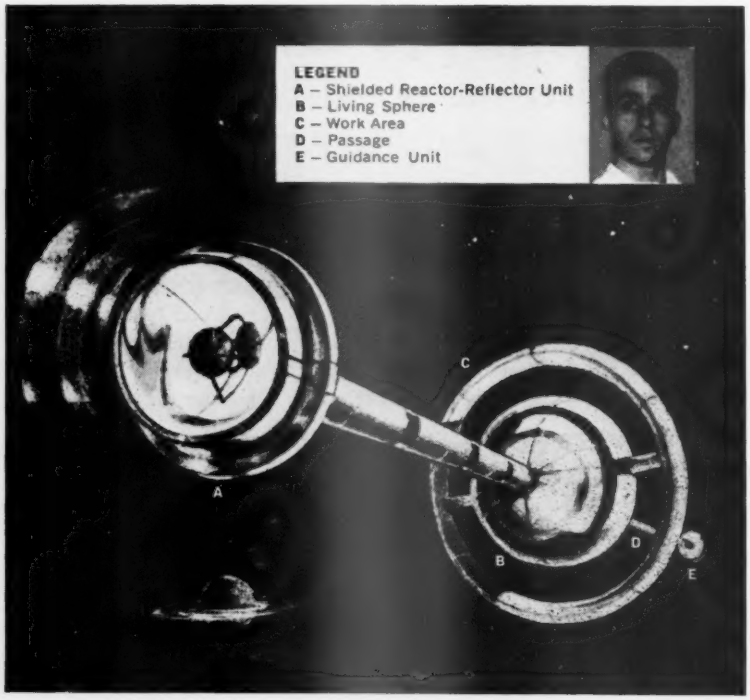
No. 17 • Mars Outstanding Design Series



LIGHT TRAVEL – You may need to postpone your trip a half century or more but you will make up for lost time. So says Philip Schlesinger, of Buffalo, N. Y., who designed this light-powered space ship which will take you to distant space at almost the speed of light.

Based on Einstein's theory that matter can be converted into light, this Photon Powered ship derives its basic power from a small atomic reactor. The reactor is housed in a unit which also contains reflectors. Comparable to fluorescent screens, these convert the reactor heat, under great pressure, into light and thrust. The thrust is low, but extremely constant.

Launched disassembled inside a cargo rocket, the ship is assembled in space. It cannot land (a landing vehicle is provided for that purpose), but remains in orbit.

This is one more example of the creative contributions today's designers are making. To help them translate their pace-setting ideas from concept to reality, they require the best of drafting tools.

In pencils that means MARS, long the standard of professionals.

Among the famous imported Mars drafting products are: **Left** – 1001 Mars-Technico push-button lead holder. **Above** – 1904 Mars-Lumograph drawing leads, 18 degrees, EXB to 9H. **Below** – 2886 Mars-Lumograph drawing pencils, 19 degrees, EXEXB to 9H; 2830 Mars-Lumograph Duralar—for drafting on Mylar®-base tracing film – 5 special degrees, K1 to K5; Mars-Lumochrom colored drawing pencils, 24 shades. **Not shown** – Mars Pocket-Technico for field use; Mars pencil and lead sharpeners; Mars Non-Print pencils and leads.

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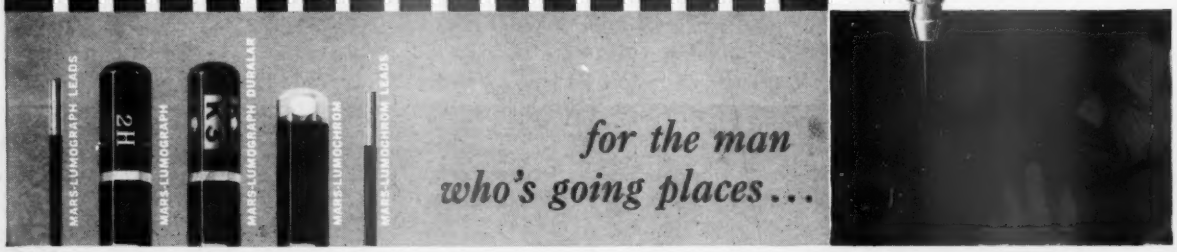

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the pencil that's as good as it looks **MARS**

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IAS News

. . . a record of people and events of interest to Institute Members

Manned Space Stations Symposium Scheduled by IAS, NASA, and RAND Corp.

Preliminary Plans for Three-Day National Symposium to Be Held April, 1960; Seven Sessions Listed

PROBLEMS INVOLVED in providing man with a habitable place in space will be given consideration and airing at a 3-day National Symposium on Manned Space Stations which will be held April 20–22, 1960, at the Ambassador Hotel in Los Angeles. The Symposium is being sponsored by the IAS, with the cooperation of the NASA and The RAND Corp. Co-chairmen are J. H. Huth and Eugene Levin of RAND.

Symposium Cochairmen
J. H. Huth Eugene Levin

Schedule of Tentative Sessions

Preliminary plans for the Symposium have scheduled general sessions on all 3 days.

The morning of April 20 will be devoted to a session on "**Current Status**" which is intended to explore the preliminary steps now in progress, to summarize the state of the art, and to indicate the reasons why a space station would be desirable. The afternoon session on "**Space Station Design Concepts**" will include several complete space station system descriptions, plus discussion of the overall cost considerations.

Three all-day sessions will be held simultaneously on April 21. They will be "**Orbit Rendezvous and Guidance**" which will cover requirements on launch times and accuracies, effect of initial errors, effect of orbit perturbations, correction of gross errors through orbit transfer, fine terminal maneuvers, ground tracking and communication requirements, vehicle-to-vehicle communication, homing devices and emergency systems; "**Human Factors**" which will include topics on requirements for a tolerable human environment, open and closed ecologies, space hazards, provision for air, food, water, heat balance, and sanitation, considerations of radiation, weightlessness, crew selection, and instrumentation; and "**Structures**" which will consider structural problems peculiar to space stations, assembly and joining techniques, design against meteoric damage and explosive failure, damping, special lightweight structures, vacuum effects, and vehicle thermal control.

Two simultaneous sessions are scheduled for the morning of April 22. One session on "**Attitude Control, Sensing and Stabilization**" will survey stability requirements and techniques for sending and controlling the orientation of incoming vehicles, as well as the station itself. The other on "**Power Supplies**" will provide a description of the power requirements of a space station and will present information on the current status of complete lightweight nuclear and solar power sources, including those systems utilizing advanced conversion techniques.

Additional Papers Invited

Although most of the papers on the program will be presented by invited speakers, a limited number of papers will be considered, subject to review, from individuals or companies desiring to submit them. Anyone interested in doing so should contact Dr. Huth or Dr. Levin at The RAND Corp., 1700 Main Street, Santa Monica, Calif.

Midwestern Meeting to Explore "New Frontiers for Aviation" Nov. 2–4

With "New Frontiers for Aviation" as its theme, the IAS National Midwestern Meeting for 1959 will take place at the Hotel Lassen, Wichita, Kan., on November 2–4. Sessions, excluding one which is classified, will be on "Techniques of Creative Thinking"; a panel discussion by representatives of Brazil, Canada, Germany, India, Italy, and the United Kingdom entitled "How Can Aviation Technology and Engineering 'Know-How' Benefit Your Area of the World?"; "A Transportation System for a New Planet"; and "New Applications of Air Vehicles."

A banquet on the evening of November 3 will honor J. Earl Schaefer, Vice-Chairman, Boeing Airplane Company, in recognition of his many contributions and dedication to the military services and the industry he has served for more than 30 years. Mr. Schaefer is retiring from active management duties. Principal speaker will be Lt. Gen. C. S. Irvine, USAF (Ret.), Director of Planning, Avco Manufacturing Co., whose remarks will be on the theme of the meeting. Toastmaster will be IAS President William Littlewood, of American Airlines.

Climaxing the meeting will be a field trip on November 4 to Fort Riley, Kan., where registrants will see a display and demonstration by The First Infantry Division of The New Pentomic Army. Host will be Major Gen. Harvey H. Fischer, Commanding.

A complete billboard-type program, listing information in detail and including security forms, has been mailed to all IAS members. It is available to others who may be interested, and inquiries should be sent to the IAS Meetings Department, 2 East 64th Street, New York 21, N.Y.

A/SE's "Green Sheet" Returning Next Month

AERO/SPACE ENGINEERING's "Green Sheet" is returning in next month's issue after a summer vacation taken in company with many Section activities.

Two Corporate Members Donate Gifts to Caltech

The Firestone Tire & Rubber Co. and Aerojet-General Corp., both Corporate Members of the IAS, have donated substantial sums to the California Institute of Technology for the construction of new research laboratories.

The Firestone gift of $1,050,000 is for the construction of a new aeronautics laboratory to be known as The Firestone Aeronautical Research Laboratory. According to Caltech officials, it will be chiefly devoted to studies of missile and aircraft structures at hypersonic speeds; design criteria for solid propellants as used in missiles, rockets, and space vehicles; flow problems at hypersonic speeds; heat transfer, including melting of surfaces exposed to hypersonic gas streams; and theoretical fluid mechanics, aimed at the discovery of fundamental laws applicable to large classes of high-speed flow problems. The proposed five-story, 30,000-sq. ft. building will house several kinds of advanced research equipment, including plasma jets, shock tubes, and electric-arc wind tunnels operating at speeds up to the equivalent of 12,400 m.p.h.

Aerojet-General has donated $400,000 for the erection of a new research laboratory which will be named in honor of Aerojet's founder, Dr. Theodore von Kármán. The new Kármán laboratory will be devoted principally to the study of jet propulsion, fluid mechanics, and hydrodynamics.

Dr. von Kármán directed Caltech's Guggenheim Aeronautical Laboratory for more than 20 years, founding the original Aerojet-Engineering Corp. in the late 1930's.

Lockheed Reorganizes Operations Into Two Groups

Lockheed Aircraft Corp., IAS Corporate Member, has announced division of its operations into two separate groups—Aircraft and Missiles-Electronics.

Gilbert N. Rosa (M) has been elected a member of the Board of Directors of Statham Instruments, Inc. Mr. Rosa retains his post as Vice-President of Marketing.

Major Richard C. Lathrop (M) has been appointed Commandant of the USAF Experimental Flight Test Pilot School at Edwards AFB, Calif. The School's mission is to train select pilots for conducting flight tests of experimental and production aircraft.

L. Eugene Root, IAS Fellow, was named Group Vice-President for Missiles and Electronics, and A. Carl Kotchian was appointed Group Vice-President for Aircraft.

Mr. Root has been Vice-President and General Manager of the Missile and Space Division at Sunnyvale, Calif., since 1956. His new responsibilities cover the Missiles Division, the newly formed Electronics and Avionics Division, and the recently acquired subsidiary Stavid Engineering, Inc., of Plainfield, N.J.

Mr. Kotchian was formerly Vice-President and General Manager of the Georgia Division. His new responsibilities include the Georgia and California Divisions; Lockheed Aircraft Service, Ontario, Calif.; Lockheed Aircraft International, Los Angeles; and Lockheed Air Terminal, Burbank. Both men have been assigned to corporate headquarters in Burbank.

These changes are intended to coordinate worldwide activities, improve liaison between divisions doing similar work, and reduce the number of division general managers reporting directly to top management.

Technical Film Catalog Being Compiled for ARDC

A *Technical Motion Picture Catalog* is being compiled by the IAS under contract with the Air Research & Development Command. Listed in this *Catalog* are classified and unclassified technical films in fields of interest to the Air Force relating to military and civilian aircraft. Included are helicopters, convertiplanes and VTO's, missiles, rockets, satellites, spacecraft, aerodynamics, aerology, aeromedicine, testing, wind tunnels, materials, components, manufacturing processes, and training films.

Information relating to technical motion pictures is available to IAS members, USAF personnel, and other Government agencies and to entities under Government contract (in connection with such contract).

The *Catalog* office at 3380 N. Harbor Drive, San Diego 1, Calif., will supply bibliographies or conduct subject searches on technical motion pictures.

One set of the *Catalog* is maintained in the New York Library of the IAS at 2 E. 64th Street; IAS members may also obtain information from the Librarian.

Space Medicine Pioneer Honored

One of the first Japanese books on space medicine has been dedicated to Dr. Hubertus Strughold, IAS Fellow who is Professor of Space Medicine and Adviser for Research at the School of Aviation Medicine, Randolph AFB, Texas.

The book, entitled *Medicine and the Stars*, covers a great deal of the pioneer research work that Dr. Strughold and his colleagues began at the School in 1947. Published in Tokyo, it includes material on the simulated space cabin, hypoxia, weightlessness, and other space medicine topics being investigated at the School; also included are photos and biographical sketches of some of the School's top scientists, past and present.

It was compiled and edited by a Major General and two Colonels of the Japan Air Self Defense Force.

Special Course Completed By IAS Associate

Karlheinz O. W. Ball (A) successfully completed the 1-year diploma course in Experimental Aerodynamics at the Training Center for Experimental Aerodynamics, Rhode-Saint-Genèse, Belgium.

The Center was founded in 1956 to give engineers and scientists from NATO countries a specialized training in the techniques and practices of a modern aerodynamics laboratory, to contribute to the dissemination of knowledge in the field of fluid mechanics—particularly experimental and applied aerodynamics, and to encourage research work in this field.

An M.S. degree from a United States University and a basic knowledge of incompressible and compressible fluid mechanics are the qualifications for the admission of a U.S. citizen.

Necrology

Robert A. Mowry

Robert A. Mowry (M) died on July 18; he was 24 years of age.

He had been associated with Convair—Pomona since 1954 and, at the time of his death, was a Senior Dynamics Engineer with responsibility for the design of missile control systems. He was also an Assistant Professor of Mathematics at Upland College, Upland, Calif.

A graduate of Upland College himself, he received a B.A. degree in Physics in 1956; he received a M.S. degree in Aeronautics in 1958 from California Institute of Technology.

XUM

U. S. ARMY ANTI-MISSILE MISSILE

The man:

. . . a top missile scientist at White Sands, N. M., missile range where preliminary *Nike Zeus* tests take place. He is a key member of the highly specialized military-civilian team that is putting this agile anti-missile missile through its development stages.

When *Zeus* goes on active duty, it will follow Douglas *Nike Ajax* and *Hercules* missiles into service with the North American Air Defense Command. And it will be maintained by Army personnel assisted by Douglas field service men who have extensive experience in the *Nike* program.

The mission:

. . . anti-missile defense. *Zeus* will roar out from emplacements around cities and industrial and military areas to intercept approaching enemy ICBM's . . . or bombers.

CLASSIFIED

The missile:

. . . *Nike Zeus* is being developed by Douglas under a Western Electric-Bell Telephone program. System will include electronic detection gear to pick up enemy ICBM's at extreme range and then guide *Zeus* out to destroy them. Vital statistics: CLASSIFIED.

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The Nation's Partner in Defense

News of Members

Krishin P. Abichandani (M) has joined the Technical Staff of Space Technologies, Inc. He was formerly Senior Aerodynamics Engineer at Convair—Pomona.

Air Commodore Francis R. Banks (HF) has joined the Board of The Blackburn Group Ltd. He will also join the Boards of two of the companies within the Group—Blackburn Aircraft Ltd. and Blackburn Engines Ltd. Air Commodore Banks was a Director of The Bristol Aeroplane Co. Ltd. and Bristol Siddeley Engines Ltd.

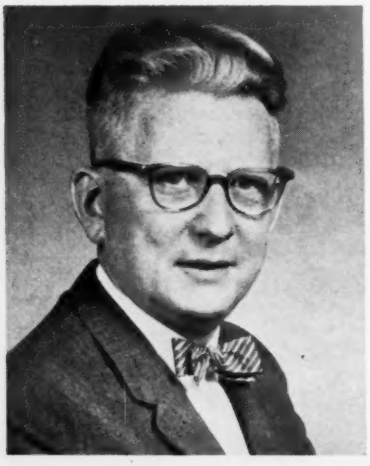
Stanley Bernstein (M) has joined Headquarters, Missile Systems Division, Raytheon Co., as Project Manager for a new missile program to be developed for the Army. He was formerly Chief—Future Projects Branch, R&D Division, Army Rocket and Guided Missile Agency at Redstone Arsenal.

Edwin T. Clark (M) has recently returned to new duties at Space Technology Laboratories, Inc. For the past year, Mr. Clark has been in England with the Air Force Ballistic Missile Division—European Office, providing systems engineering and technical advice.

Rear Adm. Luis de Florez, USN (Ret.) (F), has been named a Director of the Douglas Aircraft Corp. Admiral de Florez is a Director of National Aviation Corp., a Trustee of the American Optical Co., and President of the de Florez Co.

Edward J. Deslauriers (M) has been promoted from Aerodynamic Specialist to Assistant Project Manager, Polaris Project, at the Systems Engineering Division of Cleveland Pneumatic Industries, Inc.

T. R. Thoren (M) has been appointed Vice-President of Engineering at Pesco Products Div., Borg-Warner Corp. He was formerly associated with Thompson Ramo Wooldridge Inc. as Staff Director of Engineering Research and Development and Assistant to the Vice-President of the Ramo Wooldridge Div. In his new post, Mr. Thoren will be responsible for the R&D engineering activities at Pesco and will serve as a staff member on the policy committee.



William G. Force (A), formerly Lead Designer, Engineering Department, Chance Vought Aircraft, Inc., has joined Missiles and Space Systems, Division of United Aircraft Corp., as Senior Design Engineer.

Theodore A. George (A) has transferred from the position of Aviation Consultant to Assistant Chief of Staff for Intelligence, Department of the Army, to General Engineer with ARPA, Office of the Secretary of Defense.

M. Carl Haddon (AF) has been appointed a Vice-President of Lockheed Aircraft Corp. and General Manager of its Electronics and Avionics Division. He was formerly Chief Engineer and Director of Marketing for Lockheed's California Division.

Kenneth C. Hawkins (M), formerly with the Propulsion Products Division, Curtiss-Wright Corp., has been named Representative of the Des Moines Division of Solar Aircraft Co. for the eastern area of the United States with headquarters in Washington, D.C. He has been associated with Washington sales activities for the past 20 years.

Dr. Rudolf Hermann (M) has been appointed Technical Director of Hypersonic Facilities, Rosemount Aeronautical Laboratories, University of Minnesota. He will be in charge of all primary contracts and research for investigations involving hypersonic facilities.

Dr. Paul A. Libby (M) has been appointed Assistant Director of the Aerodynamics Laboratory of the Polytechnic Institute of Brooklyn. Dr. Libby holds the rank of Professor of Aeronautical Engineering on the Polytechnic faculty.

Dr. Angelo Miele (AF) has been appointed Director of Astrodynamics and Flight Mechanics in the Scientific Research Laboratories of Boeing Airplane Co. He was formerly associated with Purdue University as a Professor of Aeronautical Engineering.

Dr. Felix Nagel (AF) has joined Technical Operations, Inc., as Scientific Adviser to the Director of Project OMEGA, which the firm operates for the Air Force. Dr. Nagel was formerly with Convair.

Dr. Louis A. Pipes (AF) has been appointed a Consultant in Systems Engineering to Gulton Industries, Inc. He will concentrate his services in two west coast divisions of the company, CG Electronics Corp. and Engineering Magnetics. Dr. Pipes is a Professor of Engineering at UCLA and is also Consultant to the Douglas Aircraft Co. and Aerosystronics Corp.

Roy J. Sandstrom (AF) has joined Bendix Aviation Corp. as Assistant General Manager of the Bendix Systems Division, Bendix Aviation Corp. He was formerly Vice-President in charge of Engineering, Bell Aircraft Corp.

Lucien A. Schmit, Jr. (A), Assistant Professor of Structures, Case Institute of Technology, has been awarded a grant from the Case Research Fund in support of his research entitled "Methods of Systematic Synthesis." It will enable the further development of structural design synthesis developed by him.

Edward G. Uhl (AF) has joined the Ryan Aeronautical Co. to fill the newly created post of Vice-President—Technical Administration. He was formerly associated with The Martin Co. as Vice-President and General Manager of its Missile Div., Orlando, Fla.

Harold H. Warden (M) has joined Lockheed Aircraft Corporation's Georgia Division as Hercules Commercial Sales Manager. He will direct the marketing of the Super Hercules, huge prop-jet airfreighter.

Howard S. Wolko (M), formerly with the Space Flight Division, Bell Aircraft Corp., has joined the Technical Staff of the Mechanics Division, AFOSR. He will plan, formulate, initiate, and monitor the Division's program of sponsored research in aerostructures.

Comdr. Robert J. Trauger, USN (M), has been assigned duty with the Atomic Energy Commission, Washington, D.C. He had been recently stationed in Honolulu, Hawaii, as the BuAer Resident Representative and was responsible for the airline-type maintenance program adopted by the Navy for use on all Airborne Early Warning Barrier Aircraft and Fleet Early Warning Aircraft in the Pacific.

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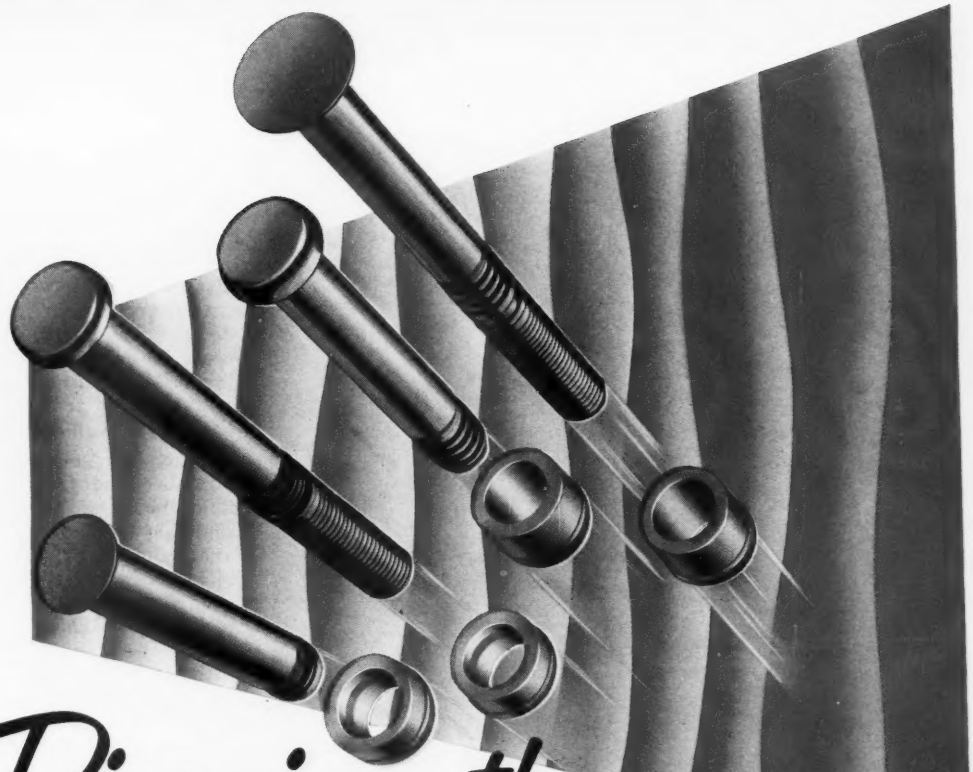

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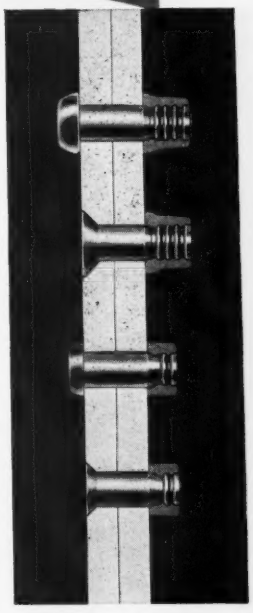

TITANIUM HUCKBOLT* FASTENERS offer up to 43% weight saving, high strength at elevated temperatures, fast installation with uniform tension and low installed cost.

Titanium Huckbolt Fasteners can save as much as half a ton per average airframe with no compromise in strength or structural integrity.

Their excellent pull-together, high clinch and swaged lock assure maximum rigidity and elimination of vibration, stripping or shake out.

Installation is so simple that inexperienced operators can install fasteners accurately and uniformly at a rate that makes other fasteners expensive and obsolete by comparison.

Removal for service or repair is simple and without work damage.

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AMF people are organized in a *single operational unit* offering a wide range of engineering and production capabilities. Its purpose: to accept assignments at any stage from concept through development, production, and service training... and to complete them faster...in

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- *Weapon Systems*
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AMF

n engineering and manufacturing AMF has ingenuity you can use... **AMERICAN MACHINE & FOUNDRY COMPA**

XUM

IAS News — Corporate Member News

• **Aerojet-General Corp.** has appointed Thomas F. Kernan as Staff Assistant to the Treasurer . . . . Sacramento Plant has designated Rudi Beichel as Project Engineer for supplying the second-stage rocket engine for the Saturn space vehicle.

• **American Airlines, Inc.,** has appointed O. T. Fleig to the post of Director of Maintenance Scheduling and Planning at its Jet Maintenance and Engineering Center in Tulsa.

• **Avien, Inc.,** has appointed William O. Boschen to the Board of Directors. He is Vice-President and General Manager of Avien.

• **Bulova Research and Development Laboratories, Inc.,** has appointed Barnett Pomerantz as Project Engineer for its Aircraft Altimeter Development and Production Programs.

• **Chicago Aerial Industries, Inc.,** has named Joe Pilolla as Chief of Manufacturing Engineering and William Erdman to the new post of Manager of Sub-Contracts.

• **Cornell Aeronautical Laboratory** has named Abraham Hertzberg to Head its Aerodynamic Research Department. The Materials Department has been regrouped with the Aerodynamic Research Department under the guidance of Division Director Franklin K. Moore, AIAS.

• **Del Mar Engineering Laboratories** has announced the addition to the staff of Cliff Sanctuary as Assistant Chief Engineer for Electronics.

• **The Garrett Corp.** has named Walker C. Brownlee as Administrative Vice-President. The promotion of Bryan S. Clark to the position of Director of Foreign Operations—Europe was also announced.

• **General Electric's** Defense Electronics Division has announced the appointment of Solomon Charp as a Consulting Engineer in the Missile and Space Vehicle Department.

• **ITT Laboratories, Division of International Telephone & Telegraph Corp.,** has announced the promotion of three engineers to Senior Scientists—Richard E. Gray, former Senior Project Engineer of the Radio Communication Laboratory, Henry F. Herbig and Malcolm C. Vosburgh, former Executive Engineers of the Wire Communication and the Avionic Systems Laboratories, respectively.

• **Lear, Inc.,** has announced the election of Albert G. Handschumacher as President of the company following the resignation of James L. Anast. Mr. Handschumacher has served on Lear's Board of Directors and as a member of its Executive Committee.

• **Meletron Corp.** has appointed Alan E. Algie as Process Engineer in Manufacturing. Gerald E. Schmitt has been named Customs Relations Manager.

• **Radio Corp. of America,** Defense Electronic Products, has announced that Richard W. Hanford has joined the engineering staff of Advanced Military Systems.

• **Space Technology Laboratories, Inc.,** has named Dr. Thomas W. Layton Associate Manager of the Inertial Guidance Department and Dr. Robert K. Whitford Associate Manager of the Controls and Simulation Department, Electromechanical Laboratory of the Research and Development Division.

• **Thompson Ramo Wooldridge Inc.** has made the following appointments in its Tapco Group: Don J. Todd as Chief of Gas Turbine Projects; John Burt Crobaugh as Manager of Power Systems Works; William P. Bente as Manager of Fuel Systems Works; and Thomas A. Johnston as Chief of Space Power Systems in the Research and Engineering Requirements Dept . . . . Thompson-Ramo-Wooldridge Products Co. has announced the following additions to the engineering staff: Malcolm E. Williams, Kraig Brigden, and Stephen Gunter. Charles E. Yingst, David L. Fellows, Donald P. Parke, and Walter A. Dienhart, Jr., have joined as Computer Programers, and Francis C. Mears as a Project Engineer.

• **Vickers, Inc.,** Division of Sperry Rand Corp., has appointed Gordon E. Stauffer as Program Administrator for the B-70/F-108 Pumping System.

• **Western Gear Corp.** has acquired a financial interest in Tridea Electronics, Inc., of Pasadena, Calif. Tridea has been active in radar, air navigation computers, automatic landing systems, electronic countermeasures, and missile guidance systems.

• **Westinghouse Electric Corp.** will establish an Astronuclear Laboratory for the development of nuclear energy for outer space. The Laboratory will be located in the Pittsburgh, Pa., district and will be part of a new Atomic Power Division. Head of the new Atomic Power Division, including the Astronuclear Laboratory, will be John W. Simpson. Technical Director of the Astronuclear Laboratory will be Dr. Sidney Krasik.

IAS News — IAS Sections

Dayton-Cincinnati Section

Nuclear Aircraft Design Topic at Joint Meeting

After 12 years of basic development work, the technology of nuclear aircraft design has advanced to the point at which practical nuclear-powered flight can be accomplished, according to **George Hatt** of Convair—Fort Worth's Nuclear Aircraft Design Project, in a talk on the "**Problems of Nuclear Aircraft Design**" at the June 11 joint meeting of the IAS and American Rocket Society. Mr. Hatt also stated that three milestones had been reached by nuclear propulsion in the last 4 years: (1) a nuclear reactor has been operated at power in flight; (2) G-E has operated jet engines on nuclear heat and is now concentrating on the development of a propulsion system for a nuclear-powered prototype; and (3) a nuclear-powered bomber design competition has been completed, with Convair selected for work with G-E on the initial design of the bomber prototype.

Nuclear aircraft faces three important design considerations, based mainly on the radiation environment—crew protection, aircraft material life, and aircraft maintainability.

Of the possible shielding arrangements, the greatest advantage has been found by dividing the shield between the nuclear reactor and crew compartment. Mr. Hatt said that Convair flew a divided shield aircraft for 28 months with an operating reactor on board. The experimental flights provided data for shield design from sea level to altitudes above 40,000 ft. The Aircraft Shield Test Reactor (ASTR), designed for 1 megawatt power output, was operated throughout the flight range with numerous shielding configurations.

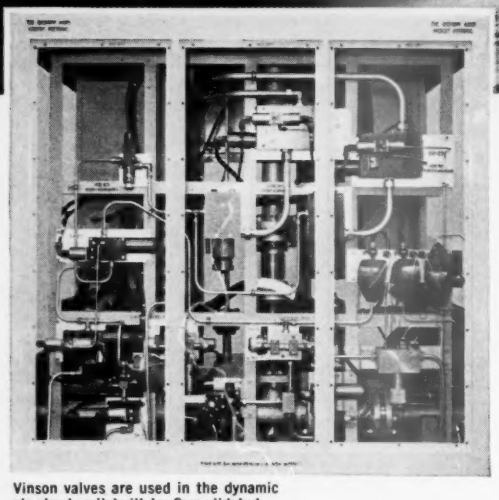
Convair, he said, has analyzed the radiation resistance and has run irradiation tests with the GTR (Ground Test Reactor) on almost every conceivable material suitable for aircraft and aircraft systems. Functional thresholds have been determined for use of these materials in a radiation environment. The threshold is based on a total radiation exposure (usually expressed in terms of REM, or roentgen equivalent man) beyond which the damage will significantly affect the material. A spectrum of thresholds show that man is the most sensitive; certain electronic components are the next most sensitive, while metals are the least. Organic materials and ceramics lie between.

From the foregoing, it is obvious that the presence of a reactor will have a significant effect on the approach toward ground support. Because of the radiation around the aircraft, protection of the ground support crew will require full shielding and completely remote operation. The maintenance operation, Mr. Hatt said, can be carried out either by shielded mobile equipment or in facilities. Mobile equipment has the advantage of a great deal more flexibility in field operations, while fixed facilities provide aircraft accessibility to larger numbers of maintenance personnel. A step toward maintenance simplicity would be removal of the reactor, the primary source of radiation, shortly after landing.

Mr. Hatt said that, in operation of the Nuclear Test Aircraft (NTA), Convair used some mobile equipment, two shielded vehicles—a tow tractor for the aircraft and a tank-track mounted "salvage"

(*Continued on page 103*)

WILL IT WORK UP HERE?



Vinson valves are used in the dynamic checkout unit built by Consolidated Systems Corporation for use in the Atlas missile program.

Behavior of helium and nitrogen valves can be predicted if you simulate conditions and pre-test on the ground. Pressure regulators, relief valves, and flow controls must be better than the systems they are checking. It takes knowledge gleaned from experience to design ground support units that guarantee expected behavior of a missile *up here.*

Vinson designed valves and regulators for both the dynamic and static checkout systems for the Atlas. Whether your control problem is simple or complex, consult Vinson engineers.

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PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

Scientist Describes Rocket of the Future

◆ Convinced that antimatter, produced in great quantities and used in photon rockets, will create unlimited possibilities for knowledge of the universe, a U.S.S.R. scientist describes the "Rocket of the Future" for the general reader, in a May issue of *Pravda Ukrainy*.

V. Cherednichenko, Candidate of Physico-Mathematics, U.S.S.R. Academy of Sciences, begins by explaining that the velocity of a rocket is determined by the velocity of the outflow of gases from the rocket. The nature of the outflowing particles plays no role; these particles can be gas molecules, atoms, electrons, ions, or photons. The latter represent from the point of view of velocity the most advantageous "working substance." The solar light pressure on the Earth is insufficient for the propulsion of a photon rocket, and the photon rocket will be provided with artificial light sources. Calculations show that an enormous light radiation power is required for creating the necessary rocket thrust. For instance, in order to communicate to a rocket weighing 100 tons an acceleration surpassing three times the acceleration of gravity, a light radiation power of 440 billions kw. is required.

Discussing the sources of light radiation, the author states that the recently discovered antiparticles—antiprotons, antineutrons, and positrons—could be used for the synthesis of antimatter, the atoms of which would have a positron shell and a nucleus consisting of antiprotons and antineutrons. The antimatter will have a negative weight and will provoke at contact with ordinary matter an explosion of great magnitude accompanied by transformation of the antiparticles into light.

Cherednichenko goes on to state that, after the problem of the economical production of antimatter and of its reliable insulation from matter—as we know it—is solved, a weightless photon rocket consisting of equal parts of matter and antimatter will be created. This rocket will require no energy for overcoming the attraction of the earth, the Soviet scientist assures his readers, and then describes a photon rocket as follows:

In the front portion of the rocket will be located the instruments, radio equipment, accommodations, and a screen for the biological protection of the travelers. The back portion will contain tanks with liquified gases of antimatter and matter. These gases will be pumped into accelerators creating a jet of gas particles falling into the focus of a giant spherical mirror with a surface of several km.^{2} where the substance and antisubstance will be transformed into light radiation. The reflection of this radiation from the mirror will create the rocket thrust.

After launching, Cherednichenko explains, the photon rocket will accelerate continuously and approach the speed of light. How soon the rocket will reach optimum sublight speed depends upon the acceleration of the rocket. The maximum acceleration endurable by man for an extended period of time, he says, is equal to triple gravity acceleration. At such an acceleration, the rocket will reach sublight speed within several months.

Touching upon the time-lag aspects of space travel, the Soviet scientist recalls that the German scientist Zenger, utilizing Einstein's theory of relativity, showed that at a sublight speed the interstellar traveler will be able during his lifetime to visit any corner of the universe regardless of how far away it should be. It follows then, Cherednichenko says, that in the rocket traveling at a triple gravity acceleration the traveler could arrive at Alpha Centauri and return to Earth within $3^1/_2$ years, according to the duration of his journey as he experienced it; meanwhile, 10 years would have elapsed upon the Earth.

Light, Plastic Gas Mask Being Readied for Norwegians

◆ According to the Norwegian Director of ABC (Atomic, Biological, Chemical) Defense, the civilian population of Norway will soon have a new lightweight plastic gas mask. This new mask stresses simplicity of design and lends itself easily to mass-production methods. Although certain minor design perfections were still under development at the time of the announcement, the production contract had been awarded to the Helly Hansen Manufacturing Co. of Moss, Norway.

The Director of ABC Defense claims that it is not intended that every inhabitant of Norway be equipped with a protective gas mask, but that the Norwegians have the capability for the rapid production of civilian gas masks, should the need arise.

"Sital" Harder Than Steel, Strong, Lighter Than Aluminum

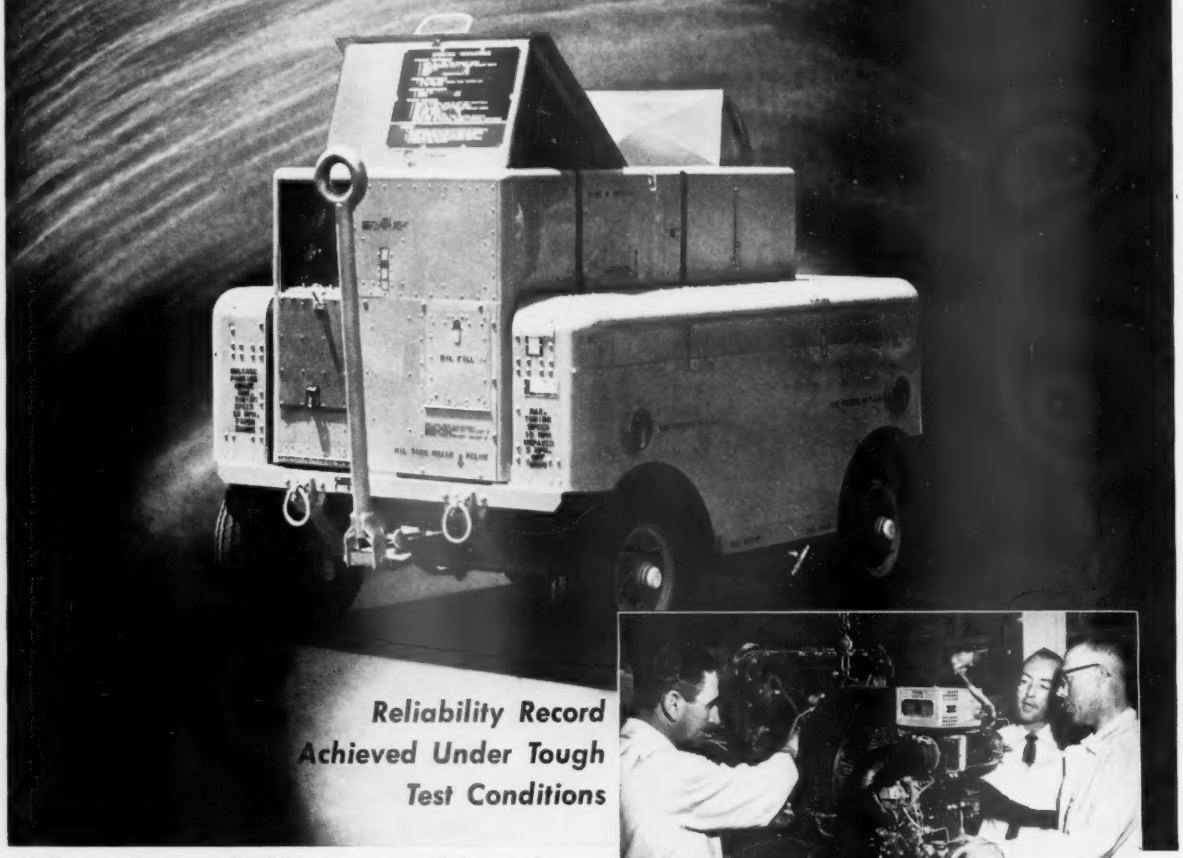
◆ A laboratory in the U.S.S.R. has developed a new material, tentatively designated "Sital," which is made from a special glass subjected to a heat treatment that changes the glass structure into a microcrystalline structure with particles about one micron in size. The laboratory director says that the new material is four times as strong as glass, harder than carbon steel, and lighter than aluminum. Its electrical properties are better than those of ceramics, he says. In heat resistance "Sital" is superior to the most heat-resistant glasses, according to its developer, and retains these properties at high temperatures. It reportedly does not soften even at 1,400°C. Wide use of "Sital" in industry is expected—for instance, it is predicted that ball bearings made from "Sital" will work an extended time in chemically aggressive media at high temperatures, and that the new material will be indispensable for making containers for storing chemical liquids.

Greater Service Life Claimed for New Rubber

◆ The Voronezh Synthetic Rubber Plant, on the Don River, in collaboration with a U.S.S.R. institute for monomers research and the Leningrad Scientific Research Institute of Synthetic Rubber, has developed a method of manufacturing synthetic rubber without preliminary thermal mastication. The developers say that properties of the synthetic rubber made by the new method are satisfactory and the production costs are the same as those for thermomasticated synthetic rubber. It is claimed that the service life of tires made from the unmasticated synthetic rubber is considerably longer than that of the tires made from standard synthetic rubber.

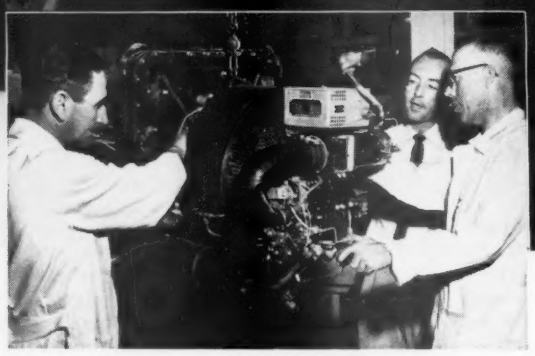
XUM

AiResearch gas turbine completes 5,000 start cycles



Reliability Record Achieved Under Tough Test Conditions

Air Force trailer-mounted MA-1A starter cart with improved AiResearch GTC 85-20 gas turbine unit.



AiResearch engineers inspecting improved AiResearch GTC 85-20 gas turbine unit after successful 5,000 start cycle test.

A world performance record for small gas turbine reliability has been established by this improved AiResearch GTC 85-20 unit... 5,000 start cycles. During each start cycle the turbine was brought to peak load twice, with a shut down time of only five minutes. This is equivalent to two main engine starts per cycle.

Throughout the entire test only routine maintenance was necessary plus replacement of one generator brush. AiResearch gas turbines now in production incorporate the improvements made in this newly tested unit.

Pneumatic power source for the Air Force's trailer-mounted MA-1A starter cart, the engine was torn down under supervision of Air Force personnel from Wright Air Development Center. It is now undergoing further tests upwards of 10,000 start cycles.

This intense product improvement in gas turbine reliability is matched only by AiResearch versatility. The world's largest manufacturer of lightweight turbomachinery, AiResearch has designed, developed and produced more than 8,500 gas turbines of all types vital to military and commercial ground support as well as auxiliary and prime power applications. Your inquiries are invited.

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EDITORIAL

The Anglo-American Conferences

Just short of 15 years ago, when some of us were only beginning to feel comfortable in civilian clothes again, a small group met at luncheon in New York to discuss a "great experiment"—a joint meeting between the aeronautical societies of Great Britain and the United States.

The idea was not wholly new. Some tentative moves in that direction had been made in the late Thirties, but, like many another peacetime project, the plans and sketches had been filed away during the war years. Some time during the spring of 1946 they were dusted off and re-examined. The exact time and place of the first discussion—and even the names of those who were present—are, in turn, buried in filing systems, but the results of that meeting stand clearly in evidence.

Soon after this issue of AERO/SPACE ENGINEERING appears, on October 4 (to be precise) the delegates of the Royal Aeronautical Society of Great Britain to the 7th Anglo-American Aeronautical Conference will be greeted by our own Officers and Council in New York's Astor Hotel. For the following 2 weeks we meet with them in joint technical sessions and in inspection trips to representative aerospace facilities in the northeastern section of the U.S. and in Canada. The project that was labeled "experiment" in 1947 has reached the status of "tradition" in 1959.

But conditions have changed, in all aspects. It is a far cry from the atmosphere of postwar London in August of 1947 to that of New York, A.D., 1959. Our first meeting was held amid the rubble of a partly destroyed city where food and most of the amenities of life were in short supply or nonexistent. (We remember the shocked surprise of some of our people over breakfasts of ersatz coffee plus glutinous oatmeal *ex* milk *or* sugar.) The scars of war were still fresh on the landscape and in people's minds. Now all is changed. Such things are almost forgotten. We meet today in an atmosphere of relaxed plenty.

As striking as they are, however, the environmental changes surrounding the 7th Conference are nothing as compared with the shift in subject matter under discussion. Who would have dared predict at our meeting in '47 that by 1958 British astronomers and physicists at Jodrell Bank would be tracking American *and Soviet* satellites in 18,000 mile per hour orbits around the Earth? Or who at that time would have thought that within a decade Mach 3 aircraft would be given serious consideration as *economic* instruments of air transport?

Such things are now commonplace in our discussions. They have led us into complexities and problems far beyond the scope of our imaginings when these Conferences began. If there was reason to pool the common technical resources of the two great English-speaking nations then, today no one can dispute the wisdom of continuing such a course. As a matter of fact, the original concept is being expanded. Canada has already been drawn into the Anglo-American Conference orbit. She will participate on an increasing scale in the future.

But possibly we are not going far enough, fast enough. Scientifically, we are in a very fluid situation where new thinking, new concepts are necessary to meet the ever-changing challenge of the aerospace age. Hopefully, the world will not always be compartmented by Iron or Bamboo Curtains. Possibly it is time to begin to measure our thinking on a truly international scale.

A beginning has already been made. The International Council of the Aeronautical Sciences established 3 years ago under the leadership of Dr. Theodore von Kármán has already held its first Congress (Madrid, September, 1958) and is planning its second for Zurich in September, 1960. Membership in the Council is open to every country in the world that has an organized society concerned with the aerospace sciences. Great interest has already been generated, and worldwide participation in the Congresses is an accomplished fact. The Royal Aeronautical Society and the IAS have played active roles in the new organization.

There is no reason why the Anglo-American Conferences and the International Congresses of ICAS cannot continue to operate concurrently. In fact, they have been scheduled for alternating years (A-A, odd; ICAS, even), to avoid conflict of dates. Suggestions have been heard, however, that the two activities should eventually be merged. The exchange of purely military information between the U.K. and the U.S. seems adequately managed via official channels, and AGARD covers NATO's requirements. It has been argued that the total number of meetings might be reduced and the scientific aspects of their coverage broadened if the exchange of information in the aerospace sciences were put on a truly international footing.

This is a matter which should not be treated lightly in view of the long-standing relationship between the Royal Aeronautical Society and the Institute. Many questions are involved which must be examined seriously by the respective Councils. It is a matter, however, to which we must face up sooner or later. It is not impossible that representatives of the two Societies will find occasion to discuss it during the forthcoming Conference.

S.P.J.

"Even at low enthalpy levels, the semiempirical nature of all turbulent boundary-layer theory demands experimental data. Fortunately, thus far . . . turbulent injection boundary-layer research enjoys a fairly academic serenity broken only by its own frustrations."

Some Experimental Techniques in Mass Transfer Cooling

Bernard M. Leadon, AFIAS
Convair Scientific Research Laboratory
Convair, A Division of General Dynamics Corporation

Introduction— Boundary Layers on Impermeable, Solid Surfaces

Boundary layers of fluid flow form on all exposed surfaces of bodies immersed in a fluid stream of relatively large dimensions. Because all fluids apparently stick to such fluid boundaries, the layers of fluid near them tend to skid over one another, subjecting all retarded layers to shearing forces in proportion to the diffusion of momentum loss outward from the surface. In this region of the flow, viscosity cannot be neglected, and its effects are seemingly endless—from the initiation of vorticity in the exterior flow,[15] to the dissipation of mechanical energy at tremendous rates,[1] and, under extreme conditions, to the generation indirectly of chemical and electrical forces.[24, 32]

As long as the state of shear is maintained by molecular viscosity only, the boundary-layer flow is laminar and amenable to numerical analysis based upon the conservation equations. Many complications can be added, such as varying the surface shape, strongly increasing the outer flow velocity, sucking away the boundary layer through holes or slots in the surface or even unsteadiness of motion[37]; and, given enough time and patience, engineering solutions can probably be obtained in each case (although even some of the classical "solutions" are not strictly valid in a mathematical sense). Even when energy dissipation reaches significant levels and heat is allowed to flow across the boundary, solutions can be obtained, and many such cases have been well verified by experiment.[9] Indeed, theory and experiment are considered to be so reliable for laminar boundary layers in subsonic and moderately supersonic exterior flows that they have been used together to measure thermodynamic properties of the fluids themselves.[11]

By contrast, no true theory exists at all for boundary layers in which the state of shear is largely maintained by random macroscopic motions superimposed upon the mean retarded flow. Neither the causes of transition from the laminar to this turbulent state nor the mechanisms of momentum, heat, and mass transfer through the turbulent boundary layer have been satisfactorily explained. One would say that the addition of complications to the turbulent boundary-layer problem at this time is clearly premature.

However, engineering often demands useful data before a basic understanding has been achieved, and this has actually been true of the turbulent boundary layer for 50 years. Consequently, a vast literature has grown up in this field. A number of ingenious assumptions have been employed which have allowed correlations of data to be made for the use of the engineer.[30, 42] The assumption, for example, that turbulent shear on an element of area is proportional to the mean velocity gradient taken normal to the area is far from correct as a description of physical reality, but, used in the conservation equations with other intuitive assumptions, it has succeeded in elucidating the dependence of several integrated boundary-layer properties such as skin friction, heat-transfer coefficients and recovery factor upon Reynolds Number, Mach Number, wall temperature, etc. After the adjustment of certain empirical constants the engineer had what he needed. Thus it was natural to use similar models of the turbulent boundary layer when it was proposed to cool the surface by injecting a coolant through pores into the boundary layer itself,[7, 33] but the approach is basically unsatisfactory and subject to suspicion when so extended.

Recently some progress has been made in the generalization of certain correlations of mean velocity data.[5, 6, 20] Although semiempirical in nature and not expected to reveal much about the inner mechanism of turbulent transport processes, this approach to the interrelationship of turbulent boundary-layer characteristics is appealing in that no artifices peculiar to the problem are required and the results are simpler in form

After research activities in aerodynamics and propulsion at Cornell Aeronautical Laboratory, Dr. Leadon returned to the University of Minnesota in 1946 to organize its Rosemount Aeronautical Laboratories. There for 11 years he directed wind-tunnel design; conducted glide bomb, transonic boundary-layer control, and heat-transfer experiments; studied supersonic slender body and boundary-layer theory; and lectured in aerodynamics. Since 1957 he has been Senior Staff Scientist in Fluid Dynamics in the Convair Scientific Research Laboratory. Educated at the College of St. Thomas and the University of Minnesota, he belongs to the IAS, APS, and ARS.

than those achieved by other methods. One may hope, therefore, to include added complications as variations of the theme, so to speak, and to make use of much established empirical information. This will help broaden our knowledge of the phenomena involved even though we may not gain appreciably in real insight. In any event, if simpler, it should be a help to the engineer.

Some Terminology

Now let us interject some terms which distinguish among the several kinds of coolant injection into an exterior boundary layer of hot gas. *Film cooling* refers to the injection, through a porous or slotted section of surface, of a liquid which subsequently wets the impermeable surface downstream and evaporates into the gas stream. *Transpiration cooling* refers to the injection through an extended porous surface of a gas of the same composition as the exterior stream. *Mass transfer cooling* is the same as transpiration cooling except that the coolant has thermodynamic properties which differ sufficiently from those of the outer flow to make mass diffusion a major factor in the behavior of the boundary layer. Of course, there are other cases such as that found downstream of transpiration through a porous section of limited length, ablation in which melting occurs, and ablation in which sublimation occurs. Also chemical reactions can occur because of the mass injection by its catalysis of the recombination of dissociated gas components or by its combustion in the exterior flow. These latter cases are all types of mass transfer cooling.

In passing it should be noted that a very interesting flow regime called *separated* flow sometimes exists near bodies. It is like a boundary layer in that its dimensions are comparable to those of the body but unlike one in that its behavior is less dominated by shear than by normal pressure gradients. Separated flow usually results from a reversal of the laminar or turbulent boundary-layer flow direction near the surface caused by a positive pressure gradient in the main flow direction which acts to decelerate the flow. In high enthalpy flows, such regions can present a surface cooling problem, and the injection of a gas coolant has been suggested as a possible means of overcoming it.[3]

Mass Transfer Cooling of the Laminar Boundary Layer

Given a knowledge of the exterior flow and of the fluid property values and in the absence of surface ablation and chemical reactions, the problem of the laminar boundary layer subjected to foreign gas injection through a smooth, porous surface, even for curved shapes and high speeds, might safely be left to the theoretician. However, these significant conditions are not generally met in cases of technical interest such as that of re-entering satellites or nose cones, filling theory with speculation and leaving perhaps the greatest uncertainty in what may be the consequences of chemical reactions should they occur. Fair engineering estimates have been made by considering extreme cases, but everyone welcomes the appearance of experimental data even for poorly simulated flight conditions. In other words, an experiment acts as an analog computation at least partly faithful to reality, and against it one can check certain theoretical assumptions.

The laminar, injection boundary-layer experiments which have been done at modest enthalpy levels may be dismissed with the remark that they either confirm theory or are suspected of being erroneous. By consulting a limited number of papers and their reference lists,[2, 10, 16, 40] the reader can in fact rapidly exhaust the subject. As to high enthalpy level laminar boundary-layer cases involving mass transfer, he is referred to two recent presentations and their nonduplicating reference lists.[14, 35]

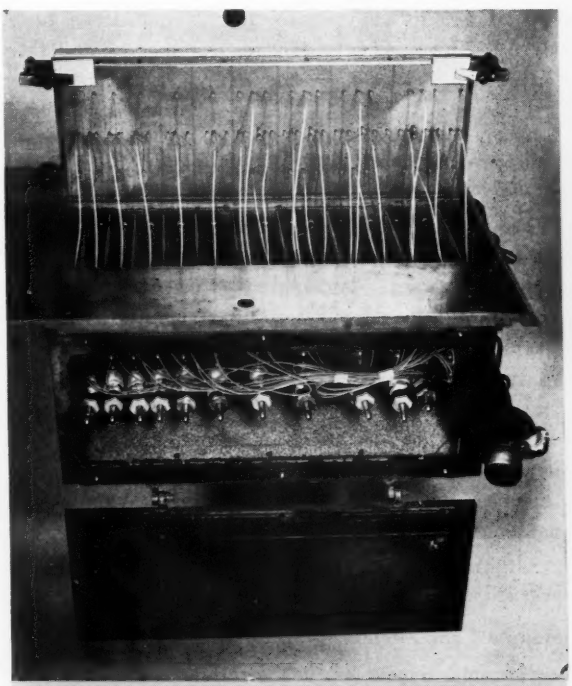

Fig. 1. Mass transfer cooling model—for installation in side wall of supersonic tunnel; shown with sintered powder test surface raised to display its underside which is extensively fitted with thermocouples and pressure taps. Compartmented chamber below is the coolant plenum chamber opened to show metering valves and vernier heaters.

Transition, as Affected by Mass Transfer

Transition from laminar to turbulent flow may be promoted by blowing through a porous surface (1) because the surface itself may be quite rough and tiny discrete jets of injected gas may effectively roughen it further, and (2) because the imposition of an injection velocity upon the laminar boundary layer tends to destabilize it. On the other hand, surface cooling in the case of high-speed flow tends to stabilize the laminar boundary layer on a smooth impermeable flat plate or cone. One wonders which effect will dominate.[39] By controlling the temperature and the flow rate of the coolant, in this case helium, it has been found possible to control the position of the transition point on a 16°, aerodynamically smooth, porous cone at a Mach Number of 3.34 outside the boundary layer.[38] By keeping the heat transfer to the wall zero and varying the injection rate, the transition point could be moved forward. Then, at a substantial injection rate, by reducing the wall temperature, the transition point could be moved progressively rearward until it was farther back than it had been with zero coolant injection. This, at least for one case, answers negatively a critical question about the practical use of porous surface injection—namely, would gas injection induce earlier transition to turbulence than would occur on a smooth impermeable surface? Such an event could possibly leave little net reduction in heat transfer to the wall because transition increases surface heating rates by an amount comparable to the reductions to be expected from air injection, for example. The lighter gases such as helium are more effective coolants, however.

Turbulent Boundary-Layer Experiments With Mass Transfer

Even at low enthalpy levels the semiempirical nature of all turbulent boundary-layer theory demands experimental data. Fortunately, thus far the higher energy conditions do not threaten to involve turbulence so turbulent injection boundary-layer research enjoys a fairly academic serenity broken only by its own frustrations. Except for the need to produce a realistic state of turbulence in the boundary layer of test models or, conversely, the lack of need to maintain laminarity, the experimental problem is one and the same for laminar and turbulent cases. As will be seen, this exception is important when a wall-mounted flat plate is chosen as test surface.

Materials and Models

The achievement of the "aerodynamically smooth" surface mentioned above represents a great amount of development work in the sintering of very fine (5 micron) stainless steel powder.[29] Only such elementary shapes as small flat sheets, hollow cones, and hemispheres (see cover illustration)* have been made so far, and control of the distribution of porosity is not yet entirely satisfactory. Previously, wrapped stainless steel wire and sintered copper or glass pellets had been used with varying degrees of success[8, 34] in making plates and cones.

Fabrication of special materials has been aided by the fact that supersonic wind-tunnel models are generally small, but their size has made difficult the incorporation of the numerous special features required of a mass transfer cooling model. There always is a hard problem of fabrication near the apex of a conical heat-transfer model which large size only mitigates. Attempts to build in a longitudinal porosity variation—required to maintain the surface at constant temperature despite the strong tendency for the forward, thinner, boundary layer to deliver more heat than the after portions—have been only partially successful; and this need for sectional control of injection had to be satisfied by partitioning and plumbing the interior. This solution, though burdensome, has one compensation beyond the resulting accuracy of control, which is that the proper blowing distribution, only approximately known for turbulent boundary layers, need not be estimated in advance but can be taken as part of the data after all of the valves are adjusted to give the desired isothermal surface.

As has been implied, the surface temperature must be taken in order to obtain heat-transfer information; this is usually done by means of small thermocouples carefully installed in the surface. Greater care must be taken to ensure that coolant does not leak around these installations and cause a false cooling of the thermocouple junction than to avoid plugging the surface pores locally. The technique developed has been to implant 0.003-in. thermocouple wires in good thermal contact with the surface material by inserting it in 0.040-in. holes drilled from the underside to within 0.025 in. of the surface and to fill the hole with a ceramic plug and a good cement. Junctions placed at several depths establish that the temperature of the outer surface is well determined. Several dozen such installations are required for a typical 6 by 16 in. flat plate model.

Leading all of these wires, plus an assortment of static pressure lead tubes, out through the compartmented coolant supply chamber may be recognized as being an intricate manipulation. Add to this the requirement for separate temperature and mass flow control for each of the coolant compartments, and one is hard pressed to house it all within the typical sharp-edged, thin, flat plate, supersonic wind-tunnel model.

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* Described on page 2. (A/SE is indebted for this color schlieren photo to the University of Minnesota Rosemount Aeronautical Laboratories, which are conducting theoretical and experimental investigations of mass transfer cooling supported by AFOSR Contract AF 18 (600)-1226. A variety of surface effusion phenomena is being considered as affected by boundary-layer character, differences in fluid properties, chemical reactions, and magnetic fields.—Ed.)

It would be almost inconceivable to do as well in a small conical model, desirable as it might be.

Fortunately for small-scale experimentation, the turbulent boundary layer on the side wall of a supersonic wind tunnel is a region in which experiments of this type can be conducted. A model surface can be flush-mounted there with all its bulky appurtenances external to the tunnel. Such a model appears in Fig. 1 with the porous surface raised to show the installed instrumentation and the plenum chamber of the coolant supply open to show the compartment control valves. The vernier heaters are not visible, but their connecting wires adjoin the valves.

Experimental Techniques

Given a model (which is a lovely thought!), the experiments must be carefully conducted in order to ensure that the assumptions which influenced its design are realized. Thus most of the techniques were established long before the tests were begun. The thermal response of the combined wind tunnel, model, and coolant supply system will dictate operating techniques in general and particularly so when the delicate zero heat-transfer condition, defining the so-called "recovery temperature" under various coolant blowing conditions, is being sought. Techniques built into the model and test section design generally are intended to facilitate keeping accurate account of the flow of thermal energy, for that is, of course, the heart of the matter.

Radiation of heat to or from the porous surface is practically intolerable and must be eliminated. The best way to do this is to control the temperature of all internal surfaces in line of sight from the test surface so as to reduce all temperature differences effectively to zero. Guard heaters must be employed extensively for this purpose, and here a small tunnel is once again appreciated.

If radiation is eliminated in this way, the problem of extraneous conduction losses through the structure will usually be greatly reduced. If important thermal gradients remain—for instance, normal to the plate at its edges—these too must be eliminated.

There then remains a simple balance of thermal energy to be considered—the heat gained by the coolant gas in passing through the pores of the surface must be equal to the sum of the heat which may possibly be generated within the surface and the heat transferred to the outer surface from the hot boundary layer. For simplicity, these three quantities should be reduced to two. Two basic techniques of evaluating the heat transfer from the boundary layer in the presence of distributed gas coolant injection are thereby suggested—raise the coolant reservoir temperature to that of the surface and measure the heat generated within or supplied internally to the surface; or measure the cooling gas energy increase in the absence of internal heat sources. Each of these two methods has certain advantages.

An excellent means of generating heat within the surface is to make it the resistance element in an electrical heating circuit.[18, 36] Although this method slightly aggravates the temperature distribution instability with regard to pore plugging, it otherwise accurately produces the ideal constant heating rates over the length of the model when the proper coolant flow distribution has been achieved by trial. If longitudinal heat conduction in the porous material is poorly resisted, however, the surface temperature distribution will be insensitive to the coolant distribution. and only the average coolant rate will have meaning. The greatest drawback with the method is the resulting need to compound the plumbing problem with the electrical insulation of the test surface and the attachment of bus bars.

Another internal heat source which has been used[44] is an array of tubing cast or otherwise inserted into the porous test surface and bearing a liquid heated externally.

Gas cooling the surface most directly simulates the idealized application.[22] This method is also probably the most practical in that the design is kept reasonably simple. Its main deficiency is that zero injection heat transfer cannot be measured. There is some danger. too, that, in making the porous surface thick enough to ensure that the temperature of the out-filtering coolant closely approaches the external temperature of the surface, its longitudinal thermal resistance will be reduced with the consequences mentioned above. Careful monitoring of the surface temperature again is required to ensure that it is sufficiently constant.

It might be added that, in addition to keeping heat fluxes under control for the sake of their measurement, the maintenance of a constant surface temperature is necessary to separate the effects of coolant injection upon heat transfer from those of surface temperature distribution, which is known to be an important variable in the zero injection case.[4]

Another technique is to measure skin friction drag directly[34] and thus to avoid much of the above travail. But obviously new problems arise, not the least of which is to relate this measurement to the heat transfer which is the real interest.

Velocity Surveys

Finally. especially in turbulent injection layers and as an academic interest in large part, it is often desirable to measure the velocity distribution very close to the surface. Typically, a low-speed, turbulent, boundary layer may be an inch or so thick, but much of the data of interest must be taken within the tenth-inch nearest the surface. Hence, to define the velocity profile adequately in this region, probes less than 0.01 in. high are generally used. In the cases in which the diffusion of the coolant is of interest, samples of the gas mixture may be drawn off for analysis externally. Surprisingly, after several years of effort, no really good data of this kind have yet been published, but it is to be hoped that this paucity of basic information will be alleviated substantially by forthcoming publications.[22, 27, 43] With it perhaps turbulent mass transfer cooling theories can be more critically evaluated and improved.

As a by-product of the velocity survey effort it has been established recently[12, 17, 31] that the skin friction drag may be evaluated by use of a single calibrated impact tube reading when it is set against the surface. This method has been shown to work in a wide variety of cases without injection, and there is reason to expect that it can be useful in transpiration cases as well.[21]

Conclusion

In its broad aspect, mass transfer cooling holds great promise as a solution to pressing technical problems. More academically viewed, it offers an interesting field for the theoretician as long as the flow remains laminar, which has been shown also to be a practical possibility. However, even at low enthalpy levels, basic studies are necessary for all turbulent boundary layers, and these will probably be principally experimental for some time to come. The injection condition at the wall represents a complication which warrants empirical investigation for its value in broadening our acquaintance with turbulent shear behavior. To this end, new techniques have been developed which seem to be about to pay off in reliable data for moderate enthalpy level conditions.

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Proposed here is a parameter for comparing the hovering performance of ground effect vehicles. This parameter is called the "Factor of Merit" and is defined as $M_F = [HW^{3/2}/(D_t^2 BHP_e)]$. *Hovering performance theory shows it is applicable to the plenum chamber and annular jet configurations.*

The parameter is compared with the "Figure of Merit" used with helicopter rotors, and its relation to efficiency is shown. Some values for ideal and actual "Factor of Merit" are also included.

A Parameter for Comparing Ground Effect Vehicles

E. K. Liberatore, AIAS
Bell Aircraft Corporation

OVER THE past few years, the interest in the ground effect vehicle (GEV) has been increasing. These vehicles, which are supported by an air cushion, are limited to operation close to the ground and are generally below a height equal to their maximum dimension.

The GEV has unique configurations although the more familiar types of vehicles could be included in this family. For example, ground limited helicopters or airplanes could be included if their major function is to operate close to the ground where the induced effects are minimized. Of the unique GEV configurations, there are four which have been receiving attention. These types are known as the "plenum chamber," "annular jet," "labyrinth seal," and the "air-film" or Levapad (Fig. 1).

Since the GEV has the ability to hover, it is of interest to evolve a parameter which can be used to compare the hovering performance of a given configuration with design changes, or to compare the hovering performance of various configurations.

In the field of vertical flight, where free rotors or ducted propellers are used, the "Figure of Merit" has been found to be a useful concept. Figure of Merit can be applied to ground effect vehicles. Its use is limited, however, because the operating height is not a parameter. In fact, Figure of Merit is not used generally for helicopters in ground effect because the value is misleading. The Figure of Merit has been derived using rotor theory, and, for this reason, it is not directly applicable to the GEV.

In view of this limitation, it is proposed here to use a new parameter for hovering performance which is derived for the GEV. This new parameter is termed the "Factor of Merit." The Factor of Merit is first derived for the plenum chamber configuration; it is then developed for the annular jet using the theory of reference 1.

Following this, some empirical values are determined.

Mr. Liberatore received his B.Ae. degree from Rensselaer Polytechnic Institute in 1942. Since that time, most of his professional work has concerned research and development in vertical flight. In 1951, the O.T.S. Department of Commerce published a series of volumes on vertical flight written for the USAF and edited by the author. Prior to joining Bell Aircraft in 1958, he was in charge of Engineering at Flettner Aircraft Corp. and later at Nagler Helicopter Co. A member of the Advanced Design Department, Mr. Liberatore has been engaged in ground effect vehicle R&D since late 1958.

Symbols

D_t = maximum diameter of sustaining area, ft. For non-circular plan forms of area A_t, the equivalent D_t is used: $D_t = \sqrt{(4/\pi)A_t}$
D_b = base diameter, annular jet
A_b = base area, ft.^{2}
A_j = jet annular area, ft.^{2}
A_t = total area, ft.^{2} $A_t = A_j + A_b$ for annular jet
W = gross weight, lbs.
H = operating height, ft., defined as in Fig. 2 (max. or design value); in general, height is defined by h
h_e = effective height of air flowing away from the plenum chamber, fps
BHP_i = ideal, air power = AHP
BHP_e = total engine power required
p = static pressure, psf
p_b = base pressure or plenum (static, gage), psf, chamber pressure
p_0 = ambient static pressure, psi
w = weight flow, lbs./sec.
Q = volume flow, cfs
V = air velocity, fps
η = AHP/BHP_e overall efficiency of compressor-duct system
M_F = Factor of Merit (max. value is implied, except as noted)
M = Figure of Merit
ρ = air density

Subscripts

1, 2, 3 = various stations
0 = ambient

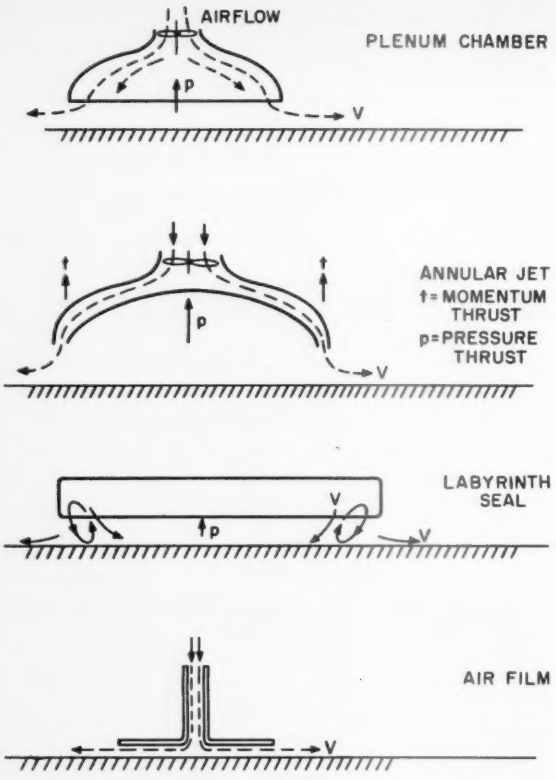

Fig. 1. Ground effect vehicle types.

With reference to Figs. 2 and 3, the notation for the theory is given in the list of Symbols.

Plenum Chamber

Fig. 2 shows the elements of the plenum chamber configurations. A circular plan form is assumed. A power plant e drives a fan or compressor c which exits into a plenum chamber. The equilibrium condition is obtained as follows. With the craft on the ground, the compressor builds up the internal pressure p_b until the craft lifts off the ground and air leaks out laterally below the chamber.

For a given power, the height at which the vehicle stabilizes is established when the weight of air pumped into the chamber equals the weight of air moving laterally out the sides. Thus

$$w_1 = w_2 = w_3$$

The velocities will be low and

$$Q_2 = Q_3 = Q$$

Also $$A_2V_2 = A_3V_3 = A_eV_e = Q$$

where A_e and V_e are effective values of area and discharge velocity, respectively. The effective area is

$$A_e = \pi(D_t + 2r)h_e$$

where r is the assumed distance to the effective height h_e measured for the periphery. Assume $h_e = \beta H$. Also

$$r = H - h_e = H(1 - \beta)$$

$$A_e = \pi\beta H[D_t + 2H(1 - \beta)]$$

The exit velocity V_e is produced by the pressure drop from 2 to ambient. The discharge velocity is defined by

$$V_e^2 = 2gJC_pT_0(P_{t_2}/p_0)^{(K-1)/K} - 1$$

for isentropic expansion of a gas from a plenum chamber with the gas at rest to free ambient air.

For the low expansion ratios where the fluid can be considered incompressible, this can be approximated by

$$V_e = \sqrt{2p_b/\rho} = \sqrt{2/\rho_0}\,\sqrt{W/A_t}\,[1/(\rho/\rho_0)^{1/2}]$$

where $W/A_t = p_b$ and $A_t = (\pi/4)D_t^2$.

The power put into the air by the fan at low-pressure ratios for isothermal compression is given by $AHP = p_bQ/550$. Thus

$$AHP = \frac{W\sqrt{2/\rho_0}\,\sqrt{W/A_t}\,\pi\beta H[D_t + 2H(1 - \beta)]}{A_t\,550(\rho/\rho_0)^{1/2}}$$

Practical values of H/D_t will be less than 0.05 and are more likely to be 0.005 to 0.01. The term β can be considered to be the discharge coefficient. Reference 6, for example, shows $\beta \cong 0.6$. Using $H = 0.05D_t$, the term $2H(1 - \beta) = 0.1D_t(0.04) = 0.04D_t$. At most, this term is 4 per cent of the total, and it is neglected. Define the overall efficiency $\eta = AHP \div BHP_e$ where η accounts for all the losses from the engine output shaft to the exit at 2. Then

$$BHP_e = \left[\frac{8\beta\sqrt{2/\rho_0}}{550\pi^{1/2}\eta(\rho/\rho_0)^{1/2}}\right] \times \frac{HW^{3/2}}{D_t^2}$$

The term in the bracket is defined as the reciprocal of the Factor of Merit M_F. Thus

$$M_F = \left[\frac{8\beta\sqrt{2/\rho_0}}{550\pi^{1/2}\eta(\rho/\rho_0)^{1/2}}\right]^{-1} = \frac{HW^{3/2}/D_t^2}{BHP_e}$$

Numerical values are given subsequently.

Annular Jet

The theoretical power requirements for the annular jet are derived in reference 1. It is of interest here to rewrite the equations in terms of Factor of Merit. The notation of reference 1 is used in the original equation. It is then converted to the present notation (Fig. 3). From reference 1:

P	=	$S/2\sqrt{\rho}\,(W/S)^{3/2}[f(S_i/S_b), (h/r_0), (\theta_0)]$
P	=	ideal power required, ft.lbs./sec.
$S = A_t$	=	total area, sq.ft.
$S_b = A_b$	=	base area, sq.ft.
$S_i = A_j$	=	area of annular jet, sq.ft.
h	=	hovering height, ft.
r_0	=	radius of base area, ft.
θ_0	=	inclination of annular jet
W	=	weight = thrust, lbs.

The function in the brackets is shown to be equal to $1/M'$ where M' is the Figure of Merit.

The theory shows the optimum condition:

$$1/M' \cong a(h/r_0)$$

where a depends on θ_0 and S_j/S_b.

Define b as follows:

$$S = bS_b = bA_b = A_t = A_j + A_b$$
$$b = 1 + (A_j/A_b)$$

Also

$$r_0 = \sqrt{A_t/\pi b}$$

$$p = \frac{A_t}{2\sqrt{\rho}}\left(\frac{W}{A_t}\right)^{3/2}\left[\frac{ah}{(A_t/\pi b)}\right]$$

The maximum height is of interest where $h = H$. Define the engine power BHP_e as before:

$$\eta = BHP_t/BHP_e = P/550\,BHP_e$$

$$BHP_e = (0.042/\eta)[ab^{1/2}/(\rho/\rho_0)^{1/2}](HW^{3/2}/D_t^2)$$

$$M_F = \frac{HW^{3/2}/D_t^2}{BHP_e}$$

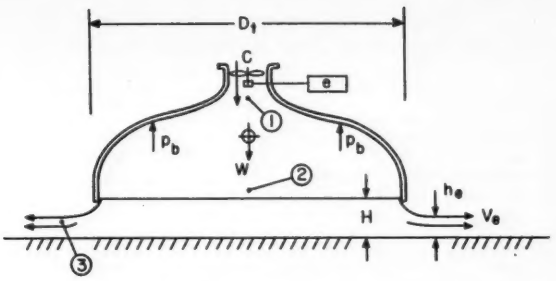

Fig. 2. Plenum chamber notation.

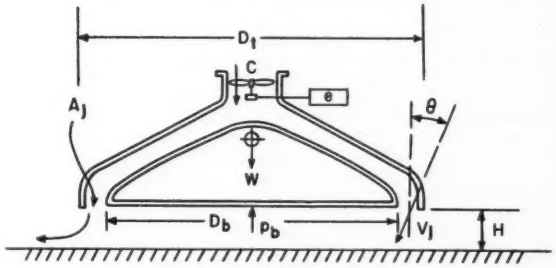

Fig. 3. Annular jet notation.

Discussion

From the foregoing, it can be seen that the plenum chamber and annular jet have the common parameter $G = HW^{3/2}/D_t^2$. This is termed the "ground effect parameter."

Thus, it can be seen, the Factor of Merit is a useful concept. It can be used for preliminary design once empirical values of M_F are found.

A high Factor of Merit is desirable for high efficiency. The ratio can be interpreted as the "amount of ground effect" delivered per engine BHP.

The maximum value of M_F is of particular interest, and for a given design it will be given by the maximum hovering height H.

The Factor of Merit is related to the Figure of Merit M. Define the latter as follows:

$$M = \frac{PL\sqrt{DL}}{38(\rho/\rho_0)^{1/2}} \qquad PL = W/BHP_e = \text{Power loading}$$
$$DL = W/A_t = \text{Disc loading}$$

Then

$$M_F = 33.8M\,(H/D_t)$$

Thus the important parameter H/D_t is shown as the multiplier to the Figure of Merit.

A high Figure of Merit obtained at the expense of a low H/D_t shows up as a relatively low Factor of Merit. From this viewpoint, the Factor of Merit is a "weighted" value of Figure of Merit.

In the other definition of Figure of Merit (as used in references 1 and 2), $M' = M/\sqrt{2}$ and $M_F = 47.6M'(H/D_t)$.

The value of BHP_e used in the equations is the value used for compression. The BHP used for forward propulsion or climb would not be included in BHP_e unless this portion can be converted into increased H.

However, BHP_e can be interpreted as the total power available as long as the power distribution is noted. This is analogous to helicopter Figure of Merit for the lifting rotor alone as compared to the overall Figure of Merit, which is lower than the former and includes the cooling losses, tail rotor power, etc.

The equations for the plenum chamber and annular jet show that there is an "internal" value for Factor of Merit:

Plenum chamber

$$M_F = \frac{1}{\dfrac{8\beta\sqrt{2/\rho_0}}{550\pi^{1/2}\eta(\rho/\rho_0)^{1/2}}}$$

Annular jet

$$M_F = \frac{1}{\dfrac{0.042}{\eta}\dfrac{ab^{1/2}}{(\rho/\rho_0)^{1/2}}}$$

For a given design, a and b are constant. If the values of β and η can be assumed constant, then the Factor of Merit will be constant for a given design.

It will be noted that there are practical limitations to height H in these equations. Both equations developed show the power required is directly proportional to height. These limitations will be defined as more test data become available.

Some values for Factor of Merit are given in Table 1. The ideal Factor of Merit for the plenum chamber is shown in Line 1. Reference 6 shows $\beta = 0.60$ for values of h/D up to 0.4. This value shows that β will be a constant for all practical plenum chamber designs. Thus, for $\beta = 0.6$, $\eta = 1.0$, and $\rho/\rho_0 = 1$, the ideal M_F for this configuration is 6.97.

Line 2 shows that a practical value of M_F for the plenum chamber configuration is approximately 5.4. Line 3 shows that the optimum, "ideal" value for the annular jet is 9.12. The latter figure is obtained by

Table 1. Some Values of Factor of Merit (M_F for Compression Only; No Propulsion, $\rho/\rho_0 = 1$)

Configuration	Conditions	Maximum M_F	Source of Data
(1) Plenum chamber Ideal	$\beta = 0.6$; $\eta = 1$	6.97	ref. 6
(2) Plenum chamber Prototype	Test data $H = 4$ in.; $BHP_e = 12$ $W = 1{,}000$ lbs.; $D_t = 12.7$ ft. equiv.	5.36	ref. 4
(3) Annular jet Ideal (Inclined jet)	Optimum, ideal $\eta = 1.0$ $A_j/A_b = 0.10$; $a = 2.07$ $b = 1.10$; $\theta > 45°$ Theoretical data	9.12	ref. 1
(4) Annular jet Ideal (Vertical jet)	Jet vertical $\theta = 0$ $A_j/A_b = 0.05$; $\eta = 1.0$ $a = 3.9$; $b = 1.05$ Theoretical data	5.92	ref. 1
(5) Annular jet	Jets vertical, model test data $BHP_e = 0.10$; $W = 1.5$ $H = 6$ in.; $D_t = 2$ ft.; $\eta < 1.0$	2.3	ref. 2
(6) Annular jet SARO	Design data $W = 4{,}000$ lbs. $\eta < 1.0$; $H = 2$ ft. $D_t = 17.8$ ft. equiv.; $BHP_e = 450$	3.6	ref. 5
(7) Annular jet Ideal*	Jets vertical $\theta = 0$ $A_j/A_b = 0.10$; $\eta = 1.0$ $a \cong 3.4$; $b \cong 1.10$	6.68	ref. 1
(8) Annular jet Ideal	Jets vertical $\theta = 0$ $A_j/A_b = 0.25$; $\eta = 1.0$ $a \cong 3.3$; $b \cong 1.25$	6.48	ref. 1

* Optimum vertical value of A_j/A_b.

inclining the jets inward to more than 45 deg. For vertical jets, the "ideal" M_F is 5.92. (The optimum values from reference 1 are assumed to be ideal values.)

Within its domain, the plenum chamber configuration shows a slightly higher ideal Factor of Merit than the annular jet configuration with vertical jets. However, the domain of the plenum chamber will probably always be closer to the ground than that of the annular jet. The limiting height occurs when the velocity across the base equals the exit velocity. There is no constriction, and $V_2 = V_e$ (Fig. 2). Thus $A_t = A_e$ and $\pi D_t^2/4 = \pi(D_t + 2r)h_e$.

Near the maximum height, $r \to 0$. Let $r = 0$, then $(H/D_t)_{max} = 1/4\beta = 0.42$. This should be the upper limit for the plenum chamber configuration regardless of power available. In theory, the annular configuration can operate out of ground effect on its jets alone. Considering exit design only, a practical plenum chamber is unable to do this.

Line 6 gives the M_F for a practical current design. A study of Lines 1 to 5 shows that the practical values of M_F are consistent with the theoretical ones.

Using Table 1 as a guide, reasonable values of M_F for preliminary design are considered to be the following:

Plenum chamber	$M_F = 5.4$
Annular jet (vertical)	$M_F = 4.0$

The Factor of Merit is related to the efficiency η as follows:

$$\eta\, M_{F_{ideal}} = M_{F_{actual}} = \frac{HW^{3/2}}{(D_t^2/BHP_e)}$$

Thus the following can be derived for the plenum chamber:

$$\eta = M_{F_{actual}}/6.97$$

For the annular jet:

Inclined jets	$\eta = M_{F_{actual}}/9.12$
Vertical jets	$\eta = M_{F_{actual}}/5.92$

The discussions of Factor of Merit and efficiency show that two general effects are present in considering overall performance. The *first* concerns the optimum design of the exit geometry. This will establish the ideal Factor of Merit. The *second* concerns the design of the compressor and ducting. This effect is implied by the actual Factor of Merit.

The distinction is important because compressor and ducting design can introduce effects that disguise an otherwise efficient exit geometry. Also, the real meaning of configuration comparisons could be lost if the distinction is not recognized. For example, the mere choice of the diameter of a fan for compression will affect the overall power requirements.

Thus the quality of the overall design is indicated by the Factor of Merit M_F, while the efficiency η will indicate the improvement possible in the design of compressor-ducting systems.

Little is known of the other two configurations of Fig. 1. However, the Factor of Merit can be used for either case in the sense of an equivalent annular jet or plenum chamber type.

Conclusions

(1) The theoretical equations show that the plenum chamber and annular jet configurations have a common parameter $[HW^{3/2}/(D_t^2 BHP_e)]$.

(2) This parameter, called the Factor of Merit, is useful for comparing hovering performance of ground effect vehicles and for obtaining preliminary hovering power requirements.

For preliminary design, $M_F = 5.4$ for the plenum chamber type and 4.0 for the vertical annular jet type.

(3) The Factor of Merit can be applied to other types of GEV in terms of an equivalent factor.

(4) Test data are required to obtain the boundaries or limitations of the Factor of Merit parameter.

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An instrument is proposed which would present a geometric interpretation of those elements of a spacecraft's orbit which define its path and position in a given plane. Actual and required orbits can be simultaneously indicated. Numerical values of all six elements of one orbit are also indicated.

The instrument may be driven automatically, semiautomatically, or manually. In any case its purpose is to assist the crew in such control problems as orbital rendezvous by assuming some of the burden of interpreting and planning.

The Orbital Plane Interpreter

Harold E. Bamford, Jr.
Boeing Airplane Company

ONE OF THE MOST important problems likely to arise in the control of a manned spacecraft is that of orbital rendezvous. This problem may be defined as the regulation of the vehicle's output so as to effect the convergence of actual and required orbits. Its solution is dependent upon the sensing of the system's input (including the feedback of output), the adjustment of its orbit, and the computation of the necessary adjustments. The various components of the input and the means of sensing them are discussed in another place.[2] There, too, are discussed the techniques of orbital change. In this report we are concerned with the computation function.

Hanes[6] has summarized the reasons for an allocation of the spacecraft system's functions which is biased toward the maximum employment of the crew. Such a design policy is assumed for the present discussion. We are concerned, then, with the assignment to a crew member of a task which consists of two dominant elements (cf. reference 3). First he must interpret a multitude of display indications and other stimuli as signs of the vehicle's orbit in relation to its required orbit. And second, he must plan on the basis of the interpreted stimuli a series of impulses which will bring about the required change. We shall not be concerned here with his sensing of stimuli or with the transmission of his judgment to the residual system, but shall confine our attention to the intervening processes of interpreting and planning.

In correlating the display indications and other components of his stimulus vector, the crew member seeks to determine the actual and required orbits of his vehicle. A variety of computing operations are performed to that end. The interpreting process would be facilitated by a framework into which he could fit the results of its various steps. Such a matrix for the interpreted stimulus is provided by the instrument whose functional specifications are the subject of this article.

Six elements are required to specify an unperturbed orbit about a primary. Of these, two serve to define the orbital plane, three a path in that plane, and one the position of a vehicle in the orbital path at a given time. For an orbital rendezvous, the full significance of the system's input is in the elements of the actual and required orbits of the vehicle. The correlation of the last four elements of each orbit (those defining path and position in the orbital plane) is performed by the orbital plane interpreter (OPI)—at least to a first approximation. The computation of the elements from the components of the stimulus vector and their communication to the OPI may be allocated to the crew member.

The plane of an unperturbed orbit about the Earth is usually specified in terms of the right ascension of its ascending node (Ω) and its angle of inclination (i). The ascending node of the orbit is the point at which the vehicle passes from the southern to the northern celestial hemisphere. The right ascension of any point is the angular distance eastward, or counterclockwise,

Dr. Bamford received his Ph.D. in psychology from the University of California in 1953. His subsequent experience in man-machine relations includes a year at the Air Force's Basic Pilot Research Laboratory, a year at the American Institute for Research, 2 years at WADC (as one of a group of psychologists from the University of Illinois), and 2 years with Ritchie and Associates, Inc., Dayton, Ohio. At the time this article was written, the author was a Senior Associate (Psychology) on the Ritchie staff. He is presently a Senior Group Engineer in the Boeing Airplane Company's Aero-Space Division, responsible for information requirements in the operation of man-machine systems.

The development reported here had its origin in a study carried out by Ritchie and Associates, Inc., and jointly sponsored by Ritchie and the USAF. The Air Force sponsorship was under the direction of Lear, Inc., of Grand Rapids, Mich., and in support of Contract No. AF 33(616)-5901, under Task No. 61940, Project No. 6190, of the WADC. Permission is granted for reproduction, publication, use, and disposal, in whole or in part, by and for the United States Government.

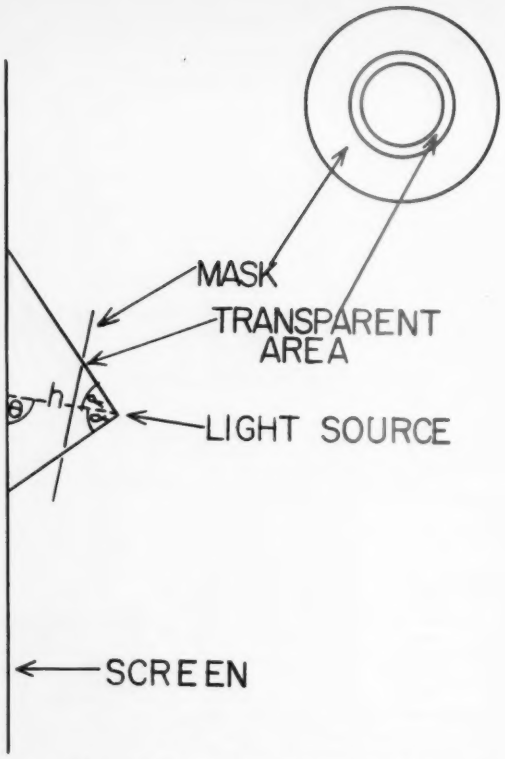

Fig. 1. Side view of the orbital plane interpreter with inset of mask.

along the celestial equator from the first point of Aries to the meridian containing that point. The angle of inclination is the angle between the orbital plane and the plane of the celestial equator. Thus Ω specifies the line of nodes, and i specifies the rotation of the orbital plane about that line. These two elements of a vehicle's orbit may be altered by an orthogonal perturbing force. They are the only orbital elements which are affected by such a force.

In the plane defined by Ω and i, the orbital path of a vehicle is specified in terms of its shape, size, and orientation. The eccentricity e of an orbit is an index of the departure of the orbit's center from its focus. Hence it indicates the shape of the orbit. The orbit's size is indicated by the length a of its transverse semiaxis. When size and shape are specified, the only remaining characteristic of an orbital path is its orientation. This is given by ω, the orbital longitude of the perigee, the longitude of any point in the orbital plane being the direction of that point from the primary, measured counterclockwise from the ascending node.

Once an orbital path has been specified by e, a, and ω in a plane specified by Ω and i, the orbit is determinate but for one element. This is usually given as T, the time of perigee passage. We shall refer instead to λ, the orbital longitude of the vehicle at any given time.

Description of the OPI

Let us turn now to a description of the OPI, whose function is to correlate the elements e, a, ω, and λ of both actual and required orbits. These elements may be computed by the crew member from various data, as we have noted. The correlation of the remaining elements, Ω and i, with each other and with these four is beyond the scope of this instrument.

The display of the OPI is a circular screen of translucent material, inscribed with concentric rings and radial lines. It is illuminated from behind, as Fig. 1 illustrates. An opaque mask is interposed between screen and light source, and the light transmitted by the transparent ring in the mask forms a hollow cone of generating angle α. The luminous projection on the screen is thus a conic section. Viewed from the front of the display, it indicates an orbital path. The position of a vehicle on the indicated path is indicated by the intersection of an adjustable radial index with the luminous projection.

The eccentricity of the projected conic is determined by the angle θ through which the conic axis of symmetry is elevated with respect to the screen. And for any θ, the size of the projected figure is determined by the length of the segment h of that axis. This is the segment which lies between the light source and the center of the screen, which is a focus of the conic section. The exact relations are given by

$$\left.\begin{aligned} e &= \cot\theta \tan\alpha \\ a &= h \tan\alpha/4 \sin\theta \end{aligned}\right\} \quad (1)$$

If $\alpha = 45°$ as in Fig. 1, these relations simplify to

$$\left.\begin{aligned} e &= \cot\theta \\ a &= h/4 \sin\theta \end{aligned}\right\} \quad (2)$$

Since eccentricity depends only on θ, the setting of the latter could well be calibrated in terms of e. However, the size of the projected figure depends not only upon h but upon θ as well. It would therefore not be possible to calibrate the settings of h in terms of a. Rather must the parameters h and θ be varied together in the representation of the orbital path. Thus a figure of constant size but increasing eccentricity could be projected only by decreasing h *pari passu* with θ, to offset the increase in a which would otherwise attend an increase in e.

And the display indication of ω, the perigee argument, can be varied by rotating the entire projection assembly about an axis perpendicular to the screen and passing through its center. Thus does the OPI afford the crew of a spacecraft a geometric interpretation of the four orbital elements which define a path and a position in a given plane.

The display of the OPI is depicted in Fig. 2. An orbital path is indicated by the luminous projection, and a position on that path is indicated by the adjustable radial index. The small solid circle at the center of the display represents the primary. The line of nodes with the celestial equator is indicated by the inscribed vertical line. The other radial lines and the concentric rings of the altitude scale are not shown.

Numerical Values of Orbital Elements

Besides the geometric interpretation, or analog indication, of orbital path and position, this display offers the numerical values of all six orbital elements. The orbital longitudes λ and ω are indicated on the circular scale at the periphery of the translucent screen, that of the vehicle by the adjustable radial index which indicates the vehicle's position, and that of perigee by an index which revolves with the projection assembly. (The orientation of the projection assembly may be adjusted by setting this latter index.) Digital memory indications of the remaining elements i, Ω, e, and a are provided, the first two in degrees of angle, the third as a dimensionless quantity, and the fourth in arbitrary units of length which can be chosen according to the operational regime or program.

The OPI may be driven by automatic computers operating on signals from input-sensing apparatus. Or, as we have indicated, the necessary computations may be performed by a crew member, who sets his results into the OPI by manipulating h and θ, the λ- and ω-indices shown in Fig. 2, and the four knobs associated in that figure with the memory indicators. A third possibility is a semiautomatic arrangement in which the crew member adjusts only the knobs and indices shown in Fig. 2, with the parameters h and θ being slaved to the a and e controls. Combinations of these three modes are clearly possible. But however its settings may be arrived at, the OPI is a matrix within which the correlation of orbital elements is accomplished.

The unperturbed orbit of a vehicle about a primary is determined by the position and velocity of that vehicle at a given instant. The interpretation of the elements of that orbit by the OPI amounts to the anticipatory indication of the vehicle's position and velocity for all subsequent instants. The anticipation is based upon the simplifying assumption of a classical two-body situation, with all perturbative effects null, including propulsion. The possible virtues of anticipatory indication have been considered elsewhere.[1, 4] In this connection it can be expected not so much to provide rapid knowledge of the results of a control action as to supply a portion of the short-term storage capacity demanded by planning.[3] By integrating the equations of motion, the OPI projects a series of output adjustments, thereby unburdening the crew member of much of the planning task (cf. reference 5).

Interpretation of Elements by the OPI

Any orbital path and position can be interpreted in the display of the OPI. Let us consider a typical application to the problem of orbital rendezvous. First, the required path and position are interpreted, or indicated in the instrument's display. These may belong to the final required orbit, to a transfer orbit between actual and target orbits, or to a transfer orbit between the actual orbit and a subsequent transfer orbit.

Next, the crew member traces the luminous projection on the translucent screen with a grease pencil or some other such implement. The result is an indication of an orbital path which will remain while another indication is projected onto the screen. The required position of the vehicle at any given time is indicated on this tracing by a second adjustable radial index (not shown in Fig. 2).

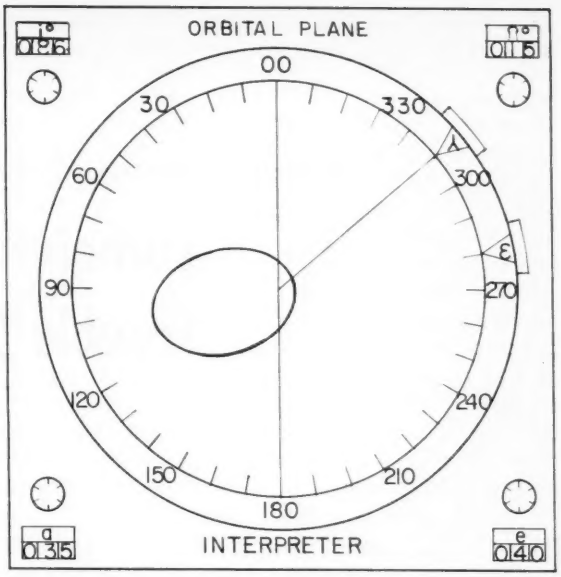

Fig. 2. Display of the orbital plane interpreter.

Then the actual path and position are interpreted. The resulting indication is an interpretation of the actual orbit of the vehicle in relation to the required orbit. (If the two orbits are not coplanar, of course, only one of them at a time can be accurately indicated by the OPI. This would ordinarily be the actual orbit. The projection of the required path onto the plane of the actual orbit could be indicated, but the orthogonal extension of the required path would be beyond the power of this instrument to interpret.)

Finally, after the orbit change, the elements of the new orbit can be interpreted, still in relation to the required orbit, whose path remains traced on the screen.

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"The economic penalties of operating at other than optimum thrust and altitude conditions are much more severe for turbine-powered aircraft than for reciprocating types."

A Practical Approach to

Turbojet Engine Management and Trouble Shooting in Flight

Edwin F. Ayers and Philip D. Doran, MIAS
Pratt & Whitney Aircraft
Division of United Aircraft Corporation

THE following remarks are intended to convey the reasoning behind the operational control techniques recommended for jet engines of current manufacture.

As in reciprocating-engine-powered practice, the thrust *required* to achieve a desired level of aircraft performance varies with ambient temperature and altitude at a rate quite different from the response of the thrust *available*. Further, and contrary to reciprocating types, net turbine engine output and resultant airspeed are interdependent—i.e., the thrust available at any given throttle position is a function of aircraft speed, and, conversely, speed is a function of engine thrust. A basic necessity to the efficient conduct of jet transport operations is, therefore, to develop *integrated* aircraft and engine performance data, and to present this to the flight crew in a form fulfilling the following requisites:

(1) It must enable the pilot to establish any desired engine operating condition and to recognize the limits thereto throughout the entire available ranges of altitude, ambient temperature, and airspeed.

(2) It must enable the pilot to predict in advance of take-off the resultant airplane performance and fuel consumption throughout the entire available ranges of gross weight, altitude, and temperature. He must know the cruise altitudes of which his particular combination of gross weight, ambient temperature, and desired airspeed is capable at limiting thrust or speed, and the time point or points at which it will be desirable to increase altitude or reduce thrust, and thus improve fuel mileage. This is absolutely essential to the achievement of maximum payload operation in the area beyond the range at which maximum take-off gross weights become limiting.

(3) In addition to knowledge of the engine factors required for the planning and conduct of flight (thrust and fuel consumption rate), it is highly desirable that the proper values and allowable tolerances of other engine indications be known, in order that engine condition may be monitored. In this way, such malfunctions as compressor contamination, excessive airbleed, foreign object damage, etc., will be exposed and their early correction facilitated.

(4) All this information must be contained in a presentation which is simple and unmistakably readable even under night flight conditions.

Integration of Engine and Aircraft Performance

To date, the great majority of modern turbine jet-powered flight experience (largely military) has been conducted with engine output controlled to produce a desired airspeed. Where traffic allowed, altitude was sometimes subsequently increased as permitted by limiting engine condition. This allowed the aircraft to arrive at destination with maximum, if unpredictable, fuel remaining. Such procedure, of course, is understandable when a precise rendezvous is of greater importance than minimum landing weight or economic engine reliability performance.

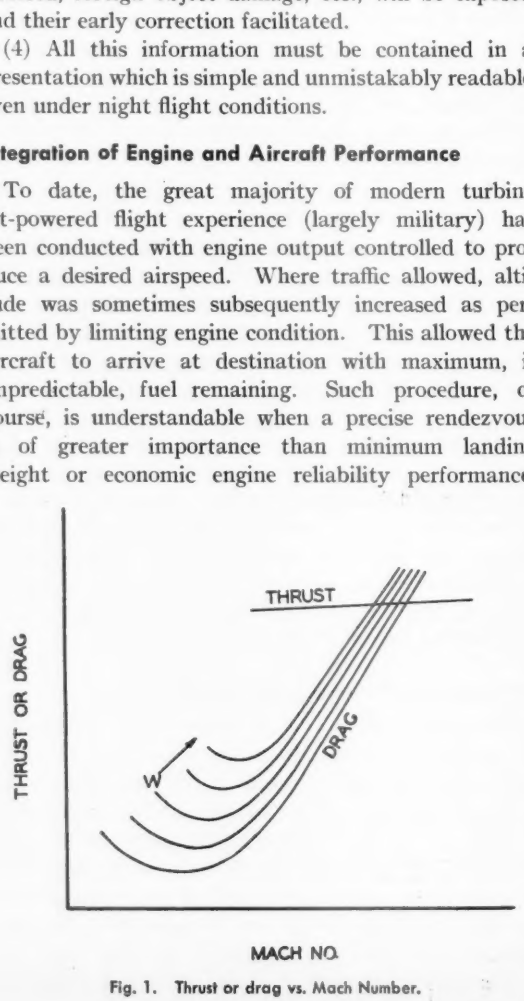

Fig. 1. Thrust or drag vs. Mach Number.

Mr. Ayers is a Flight Operations Engineer with Pratt & Whitney Aircraft. He received a B.M.E. degree from Cornell University. He was an Aviation Engineering Officer serving with the U.S. Marines in the Pacific during World War II, joining Pratt & Whitney Aircraft in 1946. He has actively participated in the development of the operating techniques for such well-known and outstanding aircraft as the Boeing 377, Convair 240, Douglas DC-6, Martin 202, the C-74, and the C-97J.

Mr. Doran is Chief, Flight Operations Engineering, of Pratt & Whitney Aircraft. He received a Bachelor's degree from Yale's Sheffield Scientific School and is in his thirtieth year with Pratt & Whitney Aircraft. Before his present assignment, he served as Experimental Test Engineer, Field Installation Engineer, Airlines Engineer, and Chief—Commercial Sales. He is the author of several papers on engine operation and performance, and played an active part in the development of the operating techniques for the first commercial long-range transocean service conducted by such aircraft as the Martin 130 China Clipper and the Sikorsky Clippers. He has since directed this type of activity for a wide variety of past and contemporary aircraft.

Commercial transport operations, however, will require a much more careful control, not only of altitude, but of fuel mileage (which often will affect allowable payload) and more precise control of engine performance. The economic penalties of operating at other than optimum thrust and altitude conditions are much more severe for turbine-powered aircraft than for reciprocating types. This is largely due to the former's greater passenger mile per hour productivity, and to the greater effect of available thrust and altitude on specific range. Modern turbine-powered transports are, in general, so designed that maximum range, as well as maximum speed and minimum direct operating cost, favor frequent use of the maximum engine output commensurate with acceptable service life. It is, therefore, likely that a considerable portion of engine operation, particularly that at take-off, climb, and cruise at high gross weight, altitude and/or above-standard ambient temperatures, will take place at or near full engine ratings. Thus, the engine rating, rather than aircraft Mach Number, will often be the controlling element in an operation designed to achieve maximum efficiency. This is the normal circumstance when the optimum sized engine is installed. The engine's ability to maintain consistently its full ratings is more than ever before an economic requisite.

The accurate presentation of engine control and monitoring information in a form suitable to the various conditions of flight requires, as stated earlier, the integration of engine and aircraft performance data. The only variable common to both is thrust, and it logically follows that the simplest and most straightforward way to prepare such an integration is first to express airplane and engine performance, each in terms of thrust required or thrust available.

Engine output *required* for any particular flight regime can be depicted simply and completely in terms of gross weight, pressure altitude, and Mach Number or in terms of gross weight, density altitude, calibrated airspeed, and (where required) rate of acceleration or climb (see Fig. 1). We shall confine the present discussion to level, unaccelerated flight, although the same concept may be applied to take-off, climb, and descent. By dividing thrust (drag) and gross weight by atmospheric pressure ratio (δ_{am}), the plot is extended to cover the desired range of pressure altitudes.

Engine *available* output, however, together with fuel flow and engine monitoring indications, varies at each operating condition (per cent maximum continuous thrust, or *MCT*) with pressure altitude, ambient temperature, and airspeed. The complexity of the relationship is such as to defy simple calculation and to require reference to published calibration data, as modified by installation losses, airbleed, and power extraction effects. Actual thrust, F_n, (or F_n/δ_{am}, to account for altitude effects) can be plotted against Mach Number at each of several engine pressure ratios (*EPR*), with reasonable accuracy throughout the pertinent flight range (see Fig. 2). *EPR* is the ratio of turbine discharge to compressor inlet pressure, and has proved to be a most useful index of net engine output. Perhaps the most important reason for its selection is that its accuracy is virtually independent of any variations in the thermodynamic effort required of

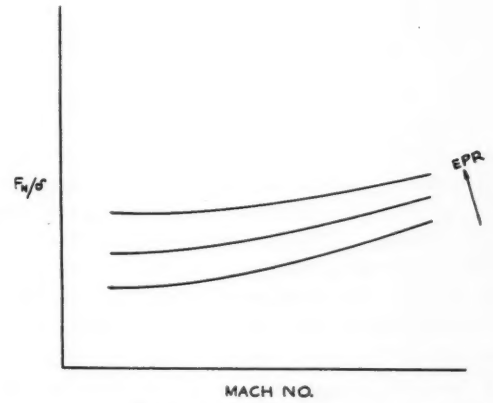

Fig. 2. F_N/δ vs. Mach Number.

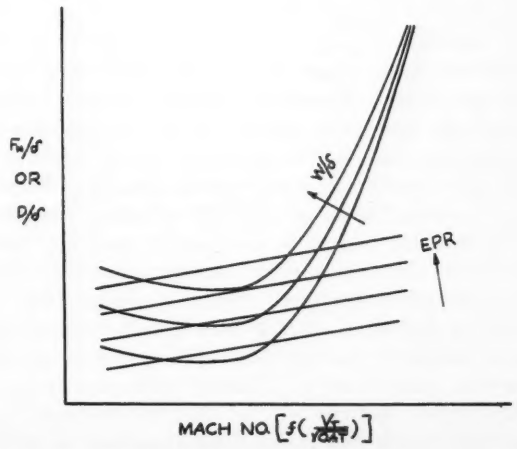

Fig. 3. F_N/δ or D/δ vs. Mach Number.

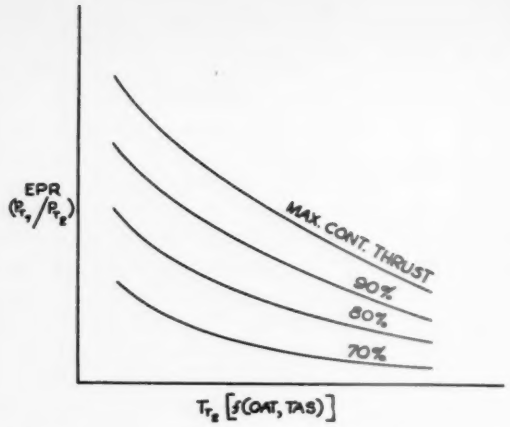

Fig. 4. Engine pressure ratio vs. compressor inlet temperature.

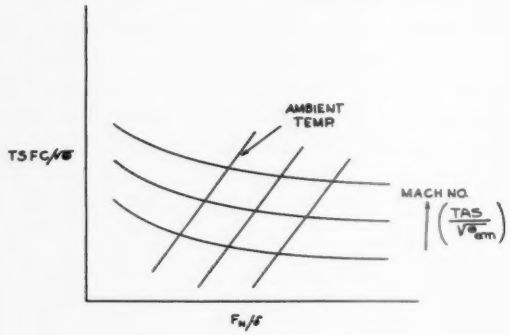

Fig. 5. $TSFC/\sqrt{\theta}$ vs. F_N/δ.

the engine components to produce a given thrust. Superimposing one on the other, we gain an idea of how the *EPR* can be established for a given speed, weight, altitude, and temperature condition (see Fig. 3). Altitude is accounted for in the δ_{am} factor, and temperature through Mach Number, which is proportional to TAS and the inverse square root of ambient temperature ratio $\sqrt{\theta_{am}}$. A difficulty arises from the fact that the *EPR* appropriate to a given engine rating, such as maximum cruise, varies with compressor inlet temperature, T_{t2} (see Fig. 4). Since T_{t2} may be comprised of various combinations of OAT and TAS, it, therefore, cannot properly be plotted against Mach Number. There are also occasions, such as at altitudes where Reynolds Number effects become important, when appropriate *EPR* is a function of altitude as well as of temperature. *EPR*, while it is normally a good indicator of actual net engine output, is not a complete index of engine operating condition until modified according to inlet temperature, and, where required, according to altitude. Fuel consumption characteristics are adaptable to a plot of $TSFC/\sqrt{\theta_{am}}$ vs. F_n/δ_{am} at each of several constant Mach Numbers (see Fig. 5). This provides all the essential ingredients of speed, altitude, ambient temperature, and thrust, so that the normal fuel flow appropriate to any flight condition may be determined. This also shows why specific range at constant Mach Number and altitude is independent of temperature, for *TAS* and fuel flow respond in equal proportion to a change in θ_{am}, or *OAT*. We now have enough information to plot a specific range curve at any desired altitude (see Fig. 6). The shape of such a curve will vary with altitude, with the peaks becoming more pronounced as altitude increases. Also, increasing altitude and temperature will reduce the available maximum cruise thrust, moving it to the left. The altitude at which maximum cruise corrseponds to desired Mach Number at the existing gross weight is the altitude which provides the best specific range at that condition, for specific range improves with altitude, and, obviously, attainable altitude increases with available thrust. There are limits to increasing altitude, of course, because at constant Mach Number the *IAS* and, therefore, *L/D* ratio will diminish to a point of longitudinal instability. Cabin pressure must also be considered.

For any desired regime of flight, whether 99 per cent maximum range, minimum direct operating cost, fixed Mach Number, fixed *TAS* or fixed *L/D*, or maximum endurance, a cross plot of that section of this type curve may be made against altitude (see Fig. 7). This curve, arbitrarily, is for maximum range. It will be obvious why increased altitude is sought as gross weight diminishes. Without the thrust available lines, this plot is independent of ambient temperature. To add such lines, it is necessary to define some fixed relation between altitude and *OAT*, such as commonly done in the ICAO "Standard" and "Hot Day" conditions. There are several interesting things in this plot.

(1) If altitude is permitted to increase, maximum range occurs at substantially a fixed Mach Number, independent of a large change in gross weight.

(2) At a given weight condition, maximum fuel mileage improves with increasing altitude until that Mach Number is reached.

(3) Step climb, rather than continuous shallow climb, costs very little in fuel or range.

(4) When limited by maximum cruise engine rating, cruise altitude and, therefore, trip fuel consumption may be appreciably different on a hot day from that on a cold day, even though specific range at constant

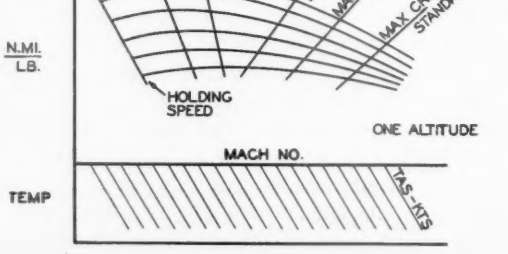

Fig. 6. Specific range curve.

Mach is known to be virtually independent of temperature.

Construction of Tables

We are now prepared to construct the integrated aircraft/engine operating charts. There are a number of ways in which this can be done. One of these is through a group of tables, each at a fixed level of engine operating condition (per cent *MCT*) separated by increments of perhaps 5–10 per cent *MCT*, in which the horizontal divisions represent separate altitudes, and the vertical columns, each subdivided into *OAT*s, represent gross weight increments (see Fig. 8). On such a chart, the blocks or elements corresponding to any desired flight regime, such as four- or three-engine long range cruise, minimum direct operating cost, constant Mach Number or maximum endurance may be shaded or outlined in such a way as to be readily discernible. With decreasing gross weight, the pilot has the option of increasing altitude, or of turning to the next lower per cent thrust chart.

The data to be included in each element is shown in Fig. 9. In addition to thrust setting, airspeed, and fuel flow information, there are included the secondary factors of rotor speeds (N_1 and N_2) and exhaust gas temperature normal for this condition. Any deviation in these secondary factors, or in fuel flow, beyond normal tolerances will signify the need for investigation of a possible malfunction. For example, contamination of compressor elements will require N_1 and/or N_2, *EGT* and possibly fuel flow to increase in order to maintain desired thrust as indicated by P_{t7} and/or *EPR*. A leaking jet nozzle may cause only N_1 and fuel flow to increase. The proper functioning of the inlet anti-icing systems may also be ascertained through these references. Airbleed for any purpose requires higher throttle position, rotor speeds, fuel flow, and *EGT* to produce the same thrust, or, alternatively, a loss in thrust (and *EPR*) at a fixed per cent *MCT* will result. With engine setting controlled as suggested here, experience will soon teach the extent of variations which are economically tolerable. These engine monitoring values are not to be confused with engine limits (which are most apt to be encountered only at *MCT* or take-off thrust), but may be regarded as measures of

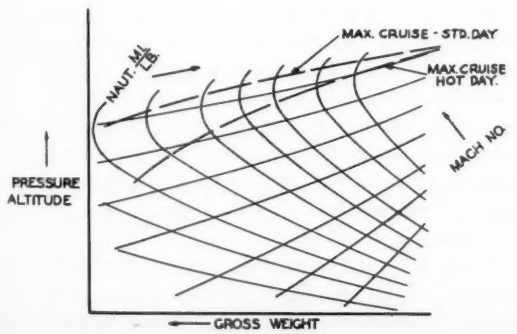

Fig. 7. Speeds for maximum specific range level flight.

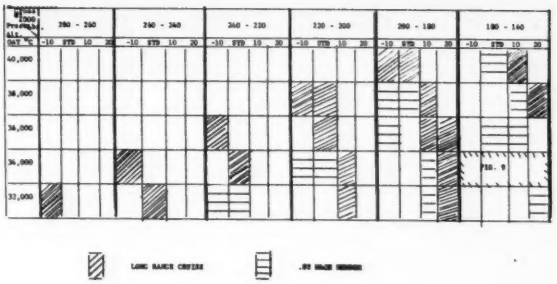

Fig. 8. 85 per cent MCT cruise chart.

PRESSURE ALTITUDE	GROSS WEIGHT	180,000 - 160,000 LBS.			
	AMBIENT TEMP.	-10	STD	+10	+20
	IAS				
	T_{ind}				
	MACH NO.				
	TAS				
34,000	OR EPR (P_{t7})				
	FUEL FLOW				
	N_1				
	N_2				
	EGT				
	TIME				
	DISTANCE				

Fig. 9. Cruise chart element.

engine deterioration, some specific degree of which is reason for correction to restore acceptable economy, or to prevent the onset of a destructive malfunction.

Such a presentation as that outlined above then fulfills the four requirements mentioned earlier—namely, to set desired engine output, to predict the associated aircraft performance, to monitor engine's condition, and to provide flight deck legibility. As a matter of interest, the use of such a chart provides no advantage for the use of *EPR* over P_{t7}. Either is equally convenient, since P_{t2} is defined by *IAS* and pressure altitude, which are fixed in each block of the tabulation. Similarly, a continuous checking of *IAS* vs. the Mach meter is facilitated, since Mach is established by *IAS* + pressure altitude/pressure altitude, also fixed.

It is, of course, possible to arrange a similar chart for each of several cruise regimes, and varying per cent *MCT* to accommodate changes in altitude, temperature, and gross weight (see Fig. 10). This is somewhat more difficult to construct but may be simpler to use where a minimum number of flight regimes is contemplated.

The point to be stressed is our belief that the most successful and efficient operation of turbine engines, just as that of reciprocating types, requires that their output be controlled and monitored according to prescribed engine indications, rather than be adjusted to obtain desired aircraft performance or limiting engine condition, whichever occurs first. Reasons include the following:

P. ALT.	G. WT.	200,000				180,000				160,000			
		-15	STD	+15	+30	-15	STD	+15	+30	-15	STD	+15	+30
30,000	% THRUST	63.8	72	85		59.8	67	78.8		54.8	61	71	83
-48°F													
-44°C	EPR	2.13	----------			2.04	----------			1.95	----------		
	N_1	5430	5580	5800		5350	5510	5700		5360	5380	5570	5760
	EGT												
	N_2	8430	8780	9000		8350	8700	8920		8280	8510	8810	9100
	W_f	11250	11580	11950		10440	10790	11140		9380	9700	10000	10310
	T_{T2}-°F	-26	2	34		-28	1	33		-30	-3	29	+60
	IAS	284	----------			280	----------			270	----------		
	TAS	449	463	478		444	459	473		427	441	455	469
	M	.785	----------			.778	----------			.748	----------		
	TIME	1:47	1:44	1:40		1:55	1:51	1:47		2:08	2:04	2:00	1:56
	DIST.	800	----------			----------				----------			
	N.MI/LB	.060	----------			.0425	----------			.0455	----------		

Fig. 10. Sample portion of long-range cruise chart.

(1) The severity of engine operating conditions, as broadly defined by internal engine temperatures, is expected to be, as in the past, a dominant factor in the determination of engine life expectancy, total aircraft direct operating cost, and daily utilization capability. Because of this, intelligent selection of the engine operating regime optimum to *any* type of mission requires that engine service experience be continually identified with engine operating conditions. Likewise, a good understanding of the conditions to which the engine is being subjected is essential to the proper design and evaluation of such improvements as service experience may indicate. The effects of unduly severe operation are accumulative and, therefore, not always manifested at the time they are incurred.

(2) For reasons pointed out earlier, it is likely that a considerable portion of engine operation will take place at or near engine maximum ratings.

(3) In instances where other than predicted aircraft performance, altitude capability, and/or fuel consumption are obtained, corrective action requires that it be known whether or not the engine is at fault.

(4) Merely to be able to set desired or limiting engine output for any flight condition is not at all sufficient for the conduct of precise flight operations. In order to dispatch an aircraft at its most efficient altitude and to determine necessary fuel loadings (sometimes affecting allowable payload), it is required that altitude capability and fuel consumption schedule be known in advance of take-off. Particularly at limiting engine output, these factors are strongly affected by ambient temperature and airspeed. Knowledge of their relationships is essential to intelligent flight planning. This can better be defined in terms of engine, rather than of aircraft, performance because the response of thrust available to a change in, say, ambient temperature is quite different from that of thrust required to support a given Mach Number or airspeed. Even where available engine ratings permit adjustment of the throttle to retain the desired speed condition, the altitude available to this configuration, and, therefore, the aircraft's optimum efficiency, will often be quite different from its value at the original temperature.

(5) In addition to the factors which are required for planning and for the conduct of flight (P_{t7} and/or *EPR*, available altitude, fuel flows, and airspeeds), it is also highly desirable that the proper values and allowable tolerances of other engine indications be known in order to monitor engine conditions, thus to expose any malfunction and to facilitate its early correction. Apart from safety and schedule reliability aspects, the economic penalty of engine performance deterioration is such as to warrant close control. N_1, N_2, *EGT* (as well as fuel flow, P_{t7} and/or *EPR*, as in *d*.) can be expressed more simply and positively in terms of engine, rather than of aircraft, performance.

Experience—Past and Future

One may recall the YC-97J and YC-121F programs in which the Pratt & Whitney Aircraft T34 turboprop engine underwent a very successful accelerated service test in MATS operation. The climb and cruise charts and procedures developed and proved during the year and one-half duration of this project have justified every confidence that this concept is a sound and workable one. The problems involved were virtually identical to those confronting a jet transport, and the only essential difference in the solution was the substitution of torque pressure for turbine discharge pressure.

It is not to be inferred that the procedures and techniques outlined above for the operation of Pratt & Whitney Aircraft turbine-powered aircraft are any more difficult or complicated than those required to achieve the same degree of refinement in any other. It will, of course, be possible to find some equivalent of the conservative 2,000 r.p.m. and 30 in. manifold pressure, or 110 per cent $V_{L/Dmax}$ *IAS* approximate power settings still used occasionally in some piston engine operations. While these usually afford a mechanically satisfactory performance, they *do not* provide for exploitation of the maximum profit potential of the aircraft. The economic rewards of more accurate flight control multiply with speed and payload capacity, and are deemed well worthy of the effort required to make precise engine and aircraft performance information available to the operating crew. The above figures are intended for this purpose.

Neither are the authors irrevocably committed to any one method of engine operation or performance presentation, for it is expected that a great deal more will be learned on the subject of maximum profit operation of turbine engines as further experience is acquired. However, as must be realized, this company has enjoyed a long, continuous, and intimate association with the practical requirements and problems of transport flight operations, knowledge of which is considered an important requisite to successful design.

On this basis, the foregoing is recommended as one procedure of engine flight control to be considered seriously in an effort to achieve the best return on the large investment in modern aircraft.

"A. . .factor, yielding as much as a 3-year shorter design development time than an equivalent program in the United States, is the decentralization of authority in their defense organization. Here [U.S.S.R.] great authority is vested in the designer himself to produce an item satisfying the proposed specifications."

The Historical Development of

Turbojet and Ram-Jet Engines in the Soviet Union

Donald J. Ritchie

Research Laboratories Division
Bendix Aviation Corporation

Mr. Ritchie received his B.S. and M.A. degrees in Mathematics and Physics from Wayne State University in 1949 and 1950, respectively, and completed all course work toward a Ph.D. degree at the University of Michigan in 1950. He is presently Project Mathematician at the Research Laboratories Division of the Bendix Aviation Corporation where he has been associated part-time since 1949. During 1957–1958, Mr. Ritchie served as Supervisor of Guided Missile Systems at the Crosley Division of Avco, and Research Branch Leader of the Advanced Analysis Branch, Scientific Analyses Office, Melpar, Inc. In 1945, he was an aircraft designer in the Design Branch, Aircraft Laboratory, WADC. His present fields of engineering and research involve the design, systems, and operation analysis of large-scale air weapons systems and advanced planning. Mr. Ritchie has amassed a collection of over 120 Soviet textbooks covering all phases of Soviet aeronautics, propulsion, and astronautics.

In order to understand and add meaning to current developments, it is always helpful to study the history of development of a given field. The following article reports on research into the historical development of jet propulsion engines in the Soviet Union. A previous study by the author into Soviet capabilities in the field of liquid propellant rockets has revealed that much information is available to the diligent searcher and indicates a high level of Soviet capability in rocket propulsion.[1]

In the present work, Soviet turbojet, ram-jet, nuclear, and advanced propulsion systems are considered. The basis of this study is the many open-shelf Soviet aeronautical texts and periodicals available in this country, as well as a detailed consideration of the commentaries of many visitors to the Soviet Union reported in the American press.

Antecedents—German Developments

It is significant to start an analysis of the historical development of Soviet jet engines with a brief review of the German efforts in the jet-engine field up to the close of World War II. This is important because at the end of World War II Russia took over much of the German jet-engine industry and many of the scientists and engineers designing and developing these engines. It is quite reasonable to anticipate that many of these scientists continued their development trends under Soviet auspices, as well as educated the Russians in their ways of approach to the problem of advanced engine design.[2]

Dipl. Ing. Helmut Schelp of the German Air Ministry (R.L.M.) considered the propulsion of aircraft at high speeds and concluded that turbojet propulsion was necessitated at aircraft speeds in excess of 500 m.p.h.[3] Accordingly, in 1938, Schelp asked all of the German aeroengine manufacturers to start a program of design and development of turbojet engines.

Heinkel began work on gas turbines in 1936 at the time von Ohain joined them. Von Ohain designed and developed the Heinkel He.S3b gas turbine which powered the first jet aircraft, the He.178.

The He.S3 comprised an axial inducer and centrifugal compressor driven by a radial inflow turbine. From it was developed the He.S8 which differed in using a straight-through annular combustion chamber. Von Ohain designed many other engines such as the He.S11, the most promising turbojet that the Germans possessed. By the close of the war, it was just going into production and had not yet become operational. Table 1 shows the characteristics of the various German turbojet engine designs.

Junkers made Germany's first gas-turbine studies in 1936. In 1939, Junkers was requested by R.L.M.

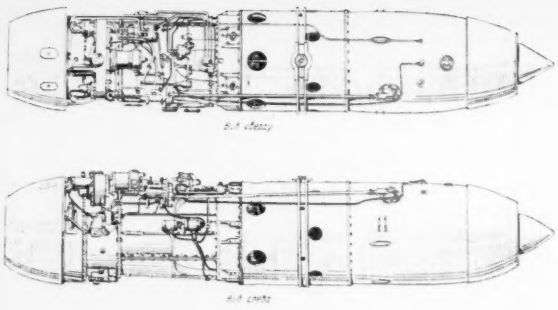

Fig. 1(a). General view of the Russian RD-10 turbojet engine—German Jumo 004. (From reference 26, p. 240.)

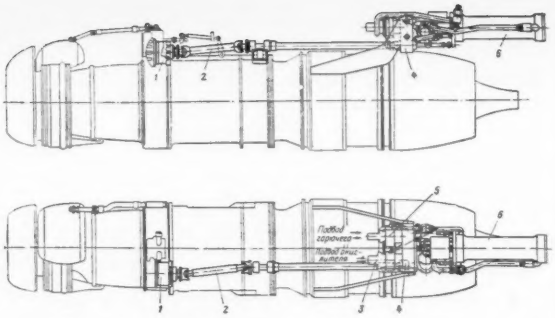

Fig. 1(b). General view of the Russian RD-20 turbojet engine with a liquid rocket booster engine—German BMW-003. (From reference 27, p. 45.)

to begin work on a half-size unit to furnish design data for the Jumo 004. This ran at 30,000 r.p.m., providing 400 s.hp. to drive the compressor—which burst shortly after and was not rebuilt. In August, 1939, work began on the Jumo 004-A. The first was tested in December, 1940, but was destroyed by a compressor stator blade failure. A long time was taken to determine the reasons for failure, so further units were not constructed until July, 1941.

The prototype Messerschmitt Me.262 flew in June, 1942, powered by two Jumo 004-A jets. The Jumo 004-B went into production and first powered the Me-262 in May, 1943.

The Bayerische Flugmoterubau (B.M.W.) began some preliminary work on gas turbines in 1934. In 1939, after Schelp's approach, Dr. Oestrich and Dr. Wolfe began studies of the P.3302. By August, 1942, the 3302 was giving 1,300 lbs. of thrust. This unit was finally developed into the B.M.W. 003-A. The 003-A2 went into large-scale production and was coming into service use in appreciable numbers at the end of the war.

The Jumo 004-B was the jet engine most used by the German Air Force, since R.L.M. policy had been to get the 004 into production as soon as possible. The B.M.W. 003 was developed to supersede it, and the He.S011 was being developed to a still more advanced state to succeed the 003. The Messerschmitt Me.262, using two Jumo 004's, achieved a top speed of 525 m.p.h. at 30,000 ft. altitude, while the He.162 using only one B.M.W. 003, reached a top speed of 520 at 20,000 ft. altitude.

In May, 1942, the Germans began the flight testing of high-temperature Lorin jet tubes.[4] The first ramjet engines were towed by truck to study injection and combustion processes. Further tests were carried out by mounting jet tubes on top of a Dornier DO.17Z. Both 2,400-hp. and 20,000-hp. units were tested.

Table 1. German Gas Turbine Engines

Engine	Thrust, lbs.	Weight, lbs.	S.F.C.	Max. R.P.M.	Diameter Length	Compressor	Turbine	Combustion Chamber
Heinkel								
He.S3	900	800	2	13,000	36.5″	1 ax 1 rad	1 rad Inflow	Annular Reverse flow
He.S8 (R.L.M.-109-001)	1,500	850		13,500	30.5″	1 ax 1 rad	1 rad Inflow	Annular
He.S10	1,500	1,100		13,500	64.5″	1 ax 1 rad	1 rad Inflow	Annular
He.S11	2,860	2,090	1.31	11,000	34.5″ 11.6″	1 ax 1 rad 3 ax	1 ax	Annular
B.M.W.								
003.A-2	1,770	1,250	1.47	9,500	27″ 10′4″	7 ax	1 ax	Annular
002.C-1	1,990	1,250		9,500	27 9′10	7 ax	1 ax	Annular
018	7,500	5,100	1.1	6,000	49″ 13′9″	12 ax	3 ax	Annular
028	7,000 hp. +3,000 T	7,700		6,000	49″ 19′	12 ax	4 ax	Annular
3306	3,760	2,000			33″ 10′6″	7 ax	1 ax	Annular
3307	1,100	1,450			27″ 9′4″	7 ax	1 ax	...
Junkers								
Jumo 004-B	1,890	1,590	1.4	8,700	21.5″ 12′8″	8 ax	1 ax	6 cans
012	6,000	4,400	1.2		42″ 17′	11 ax	2 ax	6 cans or annular
022	6,000 hp.				38.5″ 18′5″	11 ax	3 ax	...
Daimler-Benz								
007	2,650	3,000		12,500	34″ 15′3″	17 ax (3 fan)	1 ax	4 or 5 cans

The larger unit was directed toward the design of a ram-jet fighter aircraft having a climbing rate of 20,000 ft. per min. Flight speeds would be 594 knots at sea level and 513 knots in the stratosphere.

At the termination of World War II, the Soviets made a concerted attempt to get Dr. Eugen Sanger into Russia. It is assumed that they desired to carry on further ram-jet work. However, Sanger stayed in Germany to continue his work there.

Beginnings

At the end of World War II, Germany was overrun by the Red Army and the Soviets took over much of the German jet-engine development effort. The Soviets confiscated two specific engines, the Junkers Jumo 004-B and the B.M.W. 003 (which was developed to supersede it), and put them both into production. The Jumo 004 engine was copied exactly and was designated the RD-10.[5] The B.M.W. 003 engine was also copied by the Soviets and became the RD-20.[6] Both the RD-10 and RD-20 were axial compressor engines, as shown in Figs. 1(a) and (b).

The designation RD stands for *reaktivnyi dvigatel*, which is the Russian equivalent of *jet engine*. The RD-10 and RD-20 served the Soviets for the time period between 1945 and 1947. The 2,200-lb. thrust RD-10 served as power plant for the Mig-9 (Fargo) and the Yak-17 (Feather), while the RD-20 was also used in the MIG-9. It is surprising that the Soviets did not push the development of the He.S011 which was being developed to supersede both the Jumo 004 and the B.M.W. 003 by the Germans and which was nearing production at the termination of the war.

In 1947, 25 Rolls-Royce-manufactured Nene turbojet engines and 30 Derwent turbojet engines were exported to the Soviet Union.[7] These engines were copied by the Soviets, converted to Russian standards of design, and manufactured by Chelomey and Klimov.

The 5,000-lb thrust Nene turbojet engine with a 49.5-in. frame became the RD-45F engine, and the 3,500-lb. thrust Derwent turbojet engine became the Russian RD-500.[8] These centrifugal flow compressor engines were employed in the design of the MIG-15, IL-28, and Yak-23. One RD-45 was used on the MIG-15 fighter and two on the IL-28 bomber in their initial production versions. Table 2 shows some specific characteristics of the first Soviet turbojet engines.

First Soviet Engines

The first truly Soviet turbojet engine was designed by V. Klimov in 1946. This engine, designated the VK-1 after the initials of its designer, was patterned after the RD-45 but achieved 1,000 lbs. more thrust, or 6,000 lbs. of thrust, with approximately the same frame size. Table 3 displays the various Soviet engines and some of their known characteristics. Fitted with an afterburner, the VK-1F produces 7,590 lbs. of thrust. The VK-1 engines were used on prototype MIG-15 and the MIG-17 fighter aircraft.

The VK-2 engine series was also a centrifugal compressor engine and was used on the production versions of the MIG-15 and MIG-17's. The VK-5, also designed by Klimov, was a completely new engine design using an axial compressor and having considerably higher thrust and an improved specific fuel consumption. Published sources indicate that the VK-5

Table 2. The Earliest Russian Turbojet Engines

Engine	Thrust, lbs.	Weight, lbs.	S.F.C.	Max. R.P.M.	Diameter Length	Compressor	Turbine Stages	Used On
RD-10 (Jumo 004)	2,200	1,650	1.4–1.44	8,700	30″ 150″	Axial	1	MIG-9 (Fargo) Yak-17 (Feather)
RD-20 (B.M.W. 003)	2,250	1,375	1.27	10,000	27″ 143″	Axial	1	
RD-45F (Nene)	5,000	1,612	1.07	12,500	49.5″ 78.0″	Centrifugal	1	MIG-15 (Fagot) IL-28 (Beagle)
RD-500 (Derwent)	3,600	1,280	1.03	14,700	43.0″ 83.1″	Centrifugal	1	Yak-23 (Flora)

Table 3. Current Soviet Turbojet Engines

Soviet Designation	Thrust	Weight	S.F.C.	Compressor	Designer	Used On
VK-1	6,000	1,930	...	Centrifugal	V. Klimov (1946)	2 on IL-28 Beagle
VK-1A	7,590	1,930	(VK-1 w/ab)	Centrifugal	V. Klimov	2 on IL-20 1 on MIG-15 1 on MIG-17
VK-2	5,950	...	...	Centrifugal	V. Klimov	1 on MIG-15 Fagot
VK-2JA	6,850	...	...	Centrifugal	V. Klimov	1 on MIG-17 Fresco
VK-2R	7,500	2,650	(VK-2 w/ab)	Centrifugal	V. Klimov	...
VK-5	8,690	...	0.9	Axial	V. Klimov	MIG-19, Yak-25
AM-2	6,000	4,250	...	Axial	A. Mikulin (1947)	...
AM-3	19,000	5,000	0.93	Axial	A. Mikulin	2 on Badger 4 on Bison
AM-5 (MIK-205)	10,000	3,000	0.92	Axial	A. Mikulin	MIG-19, Yak-25
(MIK-205R)	13,000	3,900	...	Axial	A. Mikulin	...
AM-9 (M-209)	14,850	5,500	...	Axial	A. Mikulin	2 on TU-104
...	22,000	...	...	...	...	1 on Fishpot

XUM

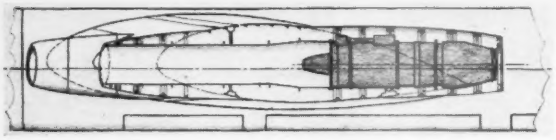

Fig. 2. Inboard profile sketch of the 19,000-lb. thrust AM-3 turbojet engine mounted in the outboard Bison engine nacelle. (Sketch by the author.)

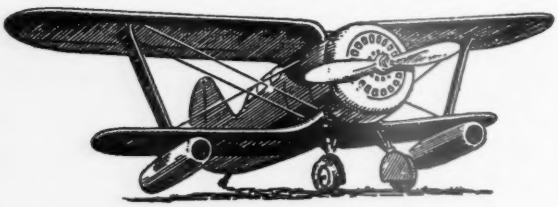

Fig. 3. Fighter aircraft I-153 Sea Gull constructed by N. N. Polikarpov with two ram-jet engines. (From reference 5, p. 51.)

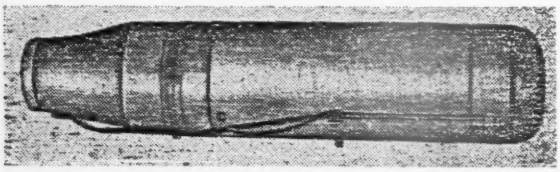

Fig. 4(a). An early Russian ram-jet engine, constructed by A. Merkulov. (From reference 22, p. 303.)

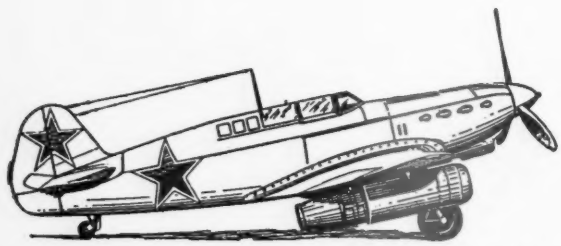

Fig. 4(b). Fighter aircraft Yak-7 constructed by A. S. Yakovlev with two Merkulov ram-jet engines—1944. (From reference 5, p. 51.)

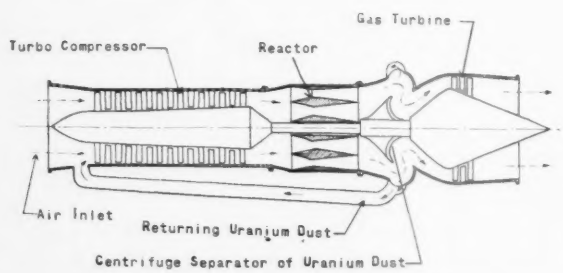

Fig. 5. Proposed nuclear turbojet engine described in Soviet literature in 1955. Clad uranium particles are circulated through active zone of the reactor to impart heat to the air. (From reference 28, p. 22.)

turbojet engine is used on the MIG-19 and Yak-25 Soviet aircraft.

A completely different series of engines has been designed under the direction of A. Mikulin. The AM-2, designed by Mikulin in 1947, was an axial compressor, 6,000-lb. thrust turbojet which served as the antecedent to a very important sequence of Russian engines.

The AM-3, two of which are used on the Badger and four on the Bison, is thought to be a 15,000- to 19,000-lb. thrust axial compressor turbojet engine. Fig. 2 shows this engine mounted in the nacelle of the Bison heavy bomber. This engine was described by Miller and Stockwell[9] as having a specific fuel consumption slightly greater than 0.9 Two smaller turbojet engines, the AM-5 and the AM-9, are used on the MIG-19 and Yak-25. Two AM-9 turbojets are used on the TU-104.

Very little information is obtainable on the Soviet's ram-jet engine program. However, early in 1939, some experimental ram-jet work was carried out by N. N. Polikarpov and I. A. Merkulov. In 1940, two ram-jet engines were mounted under the wings of the I-153 fighter airplane and were successfully flown.[10] This arrangement is shown in Fig. 3.

In 1944, a Yak-7 fighter was fitted with an improved ram-jet engine for high-speed flight. This arrangement is shown in Figs. 4(a) and (b).

A recent Soviet work worthy of special note is a small textbook by Zuyev and Skubachevsky on combustion chamber design.[11] This small book covers all phases of combustion chamber design, including such topics as fuel combustion theory, theory of flame front propagation and characteristics of burning, and the practical construction of combustion chambers and their aerodynamic characteristics.

A section of special note covers the internal design of both subsonic and supersonic ram-jet engines. This section plus the consideration of ram-jet engine control given by Bodner[12] indicates that the Soviets have carried their interests in ram-jet engines a considerable distance from their modest efforts in 1944.

Soviet Design Philosophies

In the Soviet Union, the trends of aircraft configurations—and hence the engines which power them—are determined by a relatively few individuals. The assignment of the designer's initials to a specific design is a testament to this fact. The airplane designers are Lavochkin, Mikoyan, Gurevich, Sukhoi, Ilyushin, Tupolev, and Yakovlev; the known jet-engine designers are thought to be Klimov and Mikulin. For example, it has been ascertained that Tupolev favors as few engines as possible (the Bear is an exception).[13] It is believed that this is the reason that the Russian engine designers have trended toward very large thrust turbojet engines. A further factor, yielding as much as a 3-year shorter design development time than an equivalent program in the United States, is the decentralization of authority in their defense

organization.[14] Here, great authority is vested in the designer himself to produce an item satisfying the proposed specifications. By means of the "brigade" system, a single Russian designer may have cognizance and control over many design projects at the same time.[15]

Nuclear Propulsion

There is no direct evidence that the Soviets have an aircraft nuclear engine, recent publications notwithstanding. However, all signs point to the fact that they could have one if they wanted—and it would seem that they certainly want one.

In August, 1955, at the Geneva Conference on Atomic Energy, the Soviets described the nuclear power reactor they had designed and built which was supplying a portion of Moscow with electric power. Since that time, Soviet scientists have written many articles discussing the applications and problems of nuclear reactors applied to the propulsion of aircraft. In August, 1955, Gen. G. I. Pokrovski described a nuclear turbojet design which used a uranium particle circulator scheme.[16] A diagram of this turbojet engine taken from this article is shown in Fig. 5. In the same journal, a proposal for the nuclear airplane of the future was made.

Recently a book by Nesterenko, Sushkov, and Sobolev has appeared, covering the manifold aspects of aircraft nuclear propulsion.[17] It is interesting to note the reactor design[18] shown in Fig. 6 and the schematic of a nuclear turbojet engine[19] reproduced in Fig. 7. This design considers a turbojet with the turbine drive shaft passing through the nuclear reactor. Specifications given for this engine design indicate

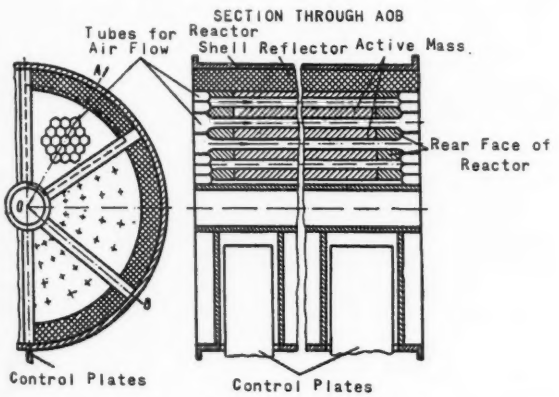

Fig. 6. Layout of uranium-beryllium homogeneous reactor for direct heating of airflow. (From reference 17, p. 58.)

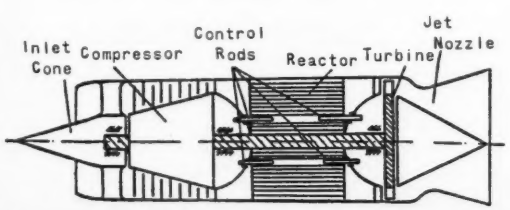

Fig. 7. Layout of atomic turbojet engine. (From reference 17, p. 90.)

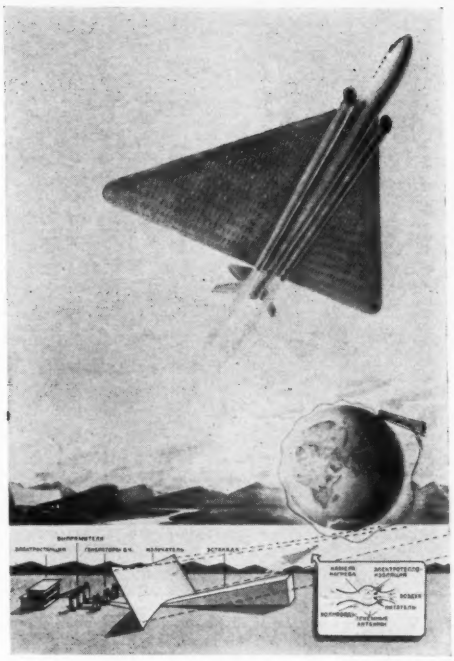

Fig. 8. Electric propulsion of hypersonic boost-glide transport aircraft. (From reference 29, p. 32.)

a sea-level thrust of about 70,000 lbs. with a total engine weight including engine, reactor, and reflector of 33,000 lbs. Engine diameter is roughly 90.6 in. and length is about 21.34 ft. It is claimed that two such engines would power a Mach 3.6 aircraft at an altitude of 36,000 ft. over a range of 540,000 nautical miles. Such an aircraft would weigh 286,000 lbs., and a total of 15 kg. of U^{235} would be consumed.[20]

Messrs. Nesterenko, Sushkov, and Sobolev consider also the design of nuclear ram-jet and rocket engines. Consideration is given to the application of the nuclear rocket to missiles and space vehicles.

Very recently, two Russian books have appeared which furnish a complete survey of jet propulsion and, specifically, ram-jet propulsion.[21, 22] These works survey the state of the art of jet propulsion and include chapters on the design of nuclear turbojet engines and ram-jet engines.

Bondaryuk and Il'yashenko condider both the design of subsonic and supersonic ram-jet engines. In the chapter on the nuclear ram-jet, a complete nuclear ram-jet engine is designed using a beryllium moderated reactor. Reactor airflow cross section is assumed to be 0.5. The reactor core diameter and length are found to be 1.54 meters, while its weight is 2.91 metric tons. The power output of the reactor is computed to be 400,000 kw.

In the final chapter of this work, the future of the ram-jet engine is discussed. It is feasible to construct nuclear reactor ram-jet engines, as well as engines operating on radioactive isotopes and beta-batteries. Interest in utilizing the dissociated oxygen in the upper atmosphere in a recombination-ram-jet engine is indicated.

Fig. 9. Russian version of manned photon propelled space ship. (From reference 25, p. 33.)

Futuristic Soviet Propulsion Schemes

Many remarkable and futuristic propulsion schemes have been appearing in recent Soviet technical literature, with mention of concepts involving high-voltage electric discharge, lightning balls, beamed electrical power, and directed and controlled plasmas.

Fig. 8, taken from the June, 1956, issue of *Tekhnika Molodezhi*,[23] the Soviet magazine of technology for the young, illustrates a proposed scheme for beaming propulsive power to a hypersonic boost-glide circumglobal transport. According to the article, the output of a nuclear power station would be coupled to a very narrow beam electromagnetic radiator, which is illustrated as a rectangular section of a paraboloid. The delta wing planform aircraft is studded with dipole pickup antennas. The beamed energy is picked up from the air, converted, and then used in the "combustion" chamber of a turbojet engine, in the form of heat, to raise the incoming air to operating temperatures.

Sufficient power is transmitted and received while the aircraft is near the power station to achieve hypersonic velocities. Away from the power transmitting station, the air transport operates as a powerless hypersonic glider. It would seem that the Soviets are capable of putting this idea into practice if it proves economically feasible. It is alleged that the Soviets now have a tram or streetcar operating on the streets of Leningrad using wireless power, and many of their journal articles describe the possible use of wireless power to drive and control automobiles on Soviet highways. Other articles illustrate the use of controlled lightning balls, plasmas, and underwater lightning for propulsion, in mining technology, and as possible weapon systems.

The Soviets seem not to overlook the possibilities of plasma-jet propulsion and are publishing extensively in this area.[24] Finally, for the long-haul interplanetary space journeys, they consider the use of photon propulsion.[25] Fig. 9 shows the Soviet's version of the photon rocket where primary power is obtained from a nuclear power generating system.

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Should the Laws of Gravitation Be Reconsidered?

Part II—Experiments in Connection With the Abnormalities Noted in the Motion of the Paraconical Pendulum With an Anisotropic Support

Maurice F. C. Allais

École Nationale Supérieure des Mines, Paris

Part I (published in the September issue) reviewed and interpreted the abnormalities observed in the motion of a paraconical pendulum on an anisotropic support.

Part II describes experiments in connection with these abnormalities—relating them to phenomena noted in mechanics, optics, and electromagnetism—and concludes that they can be accounted for "only by considering the existence of a new field."

THE IRREGULARITIES observed in the motion of a paraconical pendulum on an anisotropic support, whose order of magnitude is of approximately a few millionths of gravity, do not in fact disagree with any of the experimental results arrived at either in the astronomical domains or on the earth's surface.

The periodic irregular components of the pendulum motion appear to be in connection with the irregularities encountered during the study of multiple mechanical, optical, and electromagnetic phenomena—particularly in Michelson, Morley, and Miller's tests—and all these irregularities can probably be attributed to the same single source.

It would be advisable to continue the experimental study of these phenomena by continuous measurements over a period of at least 1 month. Such a study is of great interest for the development of a unitary theory on gravitation, electromagnetism, and quanta.

Theory

Part I outlined the very remarkable abnormalities evinced by the motion of a paraconical pendulum with an anisotropic support. These abnormalities appear to reveal some shortcomings in the currently accepted laws of gravitation.

When theory has been verified by countless facts, it is impossible to modify it slightly. In the first place, an attempt must be made at relating the new facts observed to the already known phenomena. If this appears to be impossible, which indeed is the case as I indicated, one is justified in wondering whether the abnormalities so noted can be assumed to be isolated or, again, whether they can be related to other abnormalities already noted elsewhere.

(A) Abnormalities Noted in the Classical Foucault Experiment

The bibliography of experimental research on the Foucault pendulum is extensive, but any search through it cannot fail to reveal two facts:

(1) There is a great scarcity of really significant papers.

(2) The numerical data on the results obtained are very few.

The only important experiments on the conical pendulum with numerical data on the findings are, to our knowledge, those of Bravais (1851), Willigen (1866), Kamerling Onnes (1879), Longden (1919), and Dasannacharya (1937–1939).

The experiments conducted by Bravais bore on the motion of the circular pendulum; those of Willigen, on the conical pendulum; those of Kamerling Onnes, on the asymmetrical pendulum; those of Longden, on various types of supports; while those of Dasannacharya bear on the influence of the support. The very best study by far, both from the experimental and theoretical standpoints, is that of Kamerling Onnes.[14]

Taken as a whole, these investigations strike us by the relative scarcity of observational data. To my knowledge, *the motion of the Foucault pendulum never was observed continuously, day and night, over a period of time of about a month.* Foucault himself never published the results of his findings other than in a general form,[15] and it is truly surprising to read, in the very hand of so eminent an experimenter: "Even though the amplitude of the oscillations decreases rather rapidly, they are still large enough, some five or six hours later, to reveal a deviation which is, by then, of 60 to 70 degrees,"[16] or again: "Watch in hand, it can be seen that, in Paris, the deviation is one degree in five minutes."[16]

Even though a number of spectacular experiments have been carried out (1852, the Pantheon, Paris; 1852, Cologne Cathedral; 1902, the Pantheon, Paris; 1904, Hall of Justice, Brussels; about 1930, St. Isaac Cathedral, Leningrad; 1951, Hall of Justice, Brussels; 1955, United Nations building, New York[17]), nowhere could I find the numerical series corresponding to the observations made. This is a detail which, to say the least, is surprising.

The only series I was able to find were fragmentary, but they *all include substantial abnormalities*, which are generally ascribed to defects in the support. They do give a Foucault effect, *but only on an average.*[18]

Finally, and to such an extent as might be possible on the strength of the information currently available, nobody ever achieved a perfect $-\omega \sin \lambda$ rotation other than on averages derived from numerous series of observations.

All the numerical series of observations now available—and, incidentally, there is a very small number of them—reveal, on the contrary, some variations in the rate of rotation as a function of time.

Having brought out these facts, I do not believe it would be amiss to clarify the following:

(1) The mean curve of our elementary experiments bearing on a connected series has *exactly* the Foucault slope as its tangent at the origin, when the oscillation is in a plane.

Thus our experiments are not by any means in contradiction with the general result of Foucault's experiment as has been claimed all too often.

(2) The support used for the pendulum is *anisotropic*, and it tends, on the whole, to bring back the plane of oscillation to a given direction.

The effect of this anisotropy is, on the one hand, to compensate the Foucault effect on an average during a 14-min. experiment and, on the other hand, to cause the development of ellipses, whereas, in Foucault's classical experiment, these are nearly planes.

Now there is every reason to believe that the phenomena noted, if they are not due to elliptical oscillations, are at the very least amplified by them, so that it is entirely possible for the disturbance to have a zero effect when the trajectory is plane, and a substantial effect as soon as the trajectory is elliptical.

(3) The pendulum used is a *short* one, the length of which is about 1 meter against several meters, indeed several tens of meters, as in the experiments conducted by Foucault and those who followed him. It is a known fact that it is very difficult to achieve the Foucault effect with short pendulums. Abnormalities are nearly always noted.

(4) The pendulum used can *rotate about itself*, whereas, in the Foucault pendulum, it is bound to the wire which carries it.

(5) The motion of the pendulum used was observed *without any single interruption*, day and night, for periods running to about a month. This never was the case with the Foucault pendulum.

From all these indications, it is quite clear *that nothing in the result of my experiments runs contrary to those obtained earlier*. All the earlier results, on the contrary, consistently show that there are abnormalities with respect to which we were quite remiss up to date so far as the investigation of them is concerned.

(B) Abnormalities Noted in the Realm of Mechanics

The abnormalities noted in the motion of the paraconical pendulum strike me as being closely related with the difficulties or abnormalities encountered when one has to account for a number of dynamic phenomena, which, until now, still have to be explained:

(1) Abnormalities in the tide theory.[19]

(2) Motions of the top of the Eiffel Tower.[20]

(3) Size of the deviations to the south noted on falling bodies.[21]

(4) Variations in the amplitude of the deviations to the east noted on falling bodies.[21]

(5) Abnormalities noted in the action of terrestrial rotation on the flow of liquids (Tumlirz's experiments).[22]

(6) Abnormalities noted in the motion of the horizontal gyroscope of Föppl.[23]

(7) Abnormalities noted in the experiments carried out with the isotomeograph.[24]

(8) Abnormalities noted in experiments carried out with a suspended pulley.[25]

(9) Various abnormalities noted in the geophysical measurements, ascribed until now to experimental errors.

(10) The apparently unaccountable results obtained by Louis Pasteur (General, French Medical Corps) in his experiments on the oscillation of the pendulum (1954).[26]

(11) Remarkable characteristics of the solar system, for which there has been, until now, no satisfactory explanation.[27]

To these abnormalities—which are related to motion—we should add the static types:

(1) The abnormalities of gravity. There is an excess of gravity over the ocean and a deficiency above the continents. The theory of isostasis provided only a pseudoexplanation of this, in my view.[28]

(2) The abnormalities in the experiments on Newtonian attraction. There is, on the one hand, some absorption of gravity (experiments of Majorana[29]), but also—and mainly—a variation of the Newtonian force according to the medium where it is exercised (Cremieu's experiments[30]).

Accuracy of the Verification of the Laws of Gravitation

It is not without interest, at this point, to investigate the accuracy with which the laws of gravitation are verified, both in the realm of astronomy and on the surface of the earth. This may come as a great surprise, but all the treatises of mechanics and astronomy remain notoriously silent on this fundamental question. This is a very significant gap in our knowledge and an obvious deficiency from the standpoint of scientific discipline. Any law is devoid of significance if we do not know with what degree of accuracy it has been verified.

(a) Accuracy of the Astronomical Verification of the Postulates of Mechanics

The fundamental laws of mechanics at the surface of the earth are due to an extrapolation of the results obtained in astronomy; it is not without interest, therefore, to ascertain the accuracy with which these laws actually are verified.

Unfortunately, this discussion is not given anywhere, for it is stated as a matter of principle that Newton's laws are accurately verified. Without going into a detailed discussion which would go beyond this article, it is relatively easy to determine what this degree of accuracy is.

A consideration of the remainders left by the adjustments in keeping with the least square method, as used to draw up the tables currently employed in astronomy, shows that the order of magnitude of the deviations noted for angular displacements between observation findings and theory is of some 1 sexagesimal second of arc, giving a relative error of some

$$1/90 \times 60 \times 60 \approx 3 \times 10^{-6}$$

Such is the order of magnitude of the accuracy with which Newton's laws have been verified astronomically. These laws, as all experimental ones, are verified with only some approximation. This conclusion runs counter to the ideas which are commonly accepted—without a true discussion, to be sure; but it seems to me that it must be accepted.

(*b*) *Accuracy of the Verifications of the Postulates of Mechanics at the Surface of the Earth*

The mechanical experiments at the surface of the earth which have been carried out with the greatest precision are those bearing on the pendulum which gives one second. These experiments, in effect, assume the well-known formula

$$T = 2\pi \sqrt{I/Mgl}$$

which is deduced from the postulates of mechanics. The quotient I/Ml is computed from the length measurements; T is measured and g deduced. The experiments of M. Volet at the Pavillon de Breteuil at Sèvres—which enable us to measure g directly by the photograph of the fall of invar metal rulers—enabled us to confirm the values deduced from the observations of the pendulum to 10^{-5}. Such is the order of magnitude of the accuracy with which the principles of mechanics appear to be verified at the surface of the earth.

Order of Magnitude of the Abnormalities Noted in the Motion of the Paraconical Pendulum

It is of interest to relate these figures to the order of magnitude of the abnormalities noted. This order of magnitude is that of the Foucault effect, which, in the case of the pendulum used, is itself some 3×10^{-6} of the gravity. *The effects noted, therefore, are of an order of magnitude smaller than or equal to the order of magnitude with which we may consider that the principles of mechanics are verified at the surface of the earth or in the field of astronomy.*

As a matter of fact, it should be pointed out that the abnormalities noted have a periodic structure and that, on an average, they are cancelled. If new forces must be considered, therefore, they apply only within the framework of the solar, the sidereal, or the lunar day. In the field of astronomy, where planetary motion is dealt with, it is therefore necessary to match them with forces, the integral of which would add up to zero over the path of these planets. Thus, their order of magnitude is indeed comparable to the order of magnitude with which it may be thought that Newton's laws are verified during a revolution.[31]

From this it will be seen that the abnormalities that have been revealed do not in any fashion run contrary to the earlier experimental data, either on the surface of the earth or even in the field of astronomy.

(C) Abnormalities Noted in Some Optical and Electromagnetic Phenomena

The abnormalities revealed in the motion of the paraconical pendulum with an anisotropic support strike me as having an obvious relationship with the abnormalities revealed by Michelson, Morley, and Miller in their experiments designed to show the absolute motion of the earth with respect to the ether,[32] by Esclangon on the dissymmetry of space,[33] by Fizeau in his experiments on the polarization of light,[34] and by J. Hely and P. Malsallez in their electromagnetic experiments on the anisotropy of space.[35]

It would strike me as difficult not to be impressed by the similarity in the appearances of the curves derived by Miller and others, and I can hardly refrain from concluding that all these phenomena are due to one and the same cause.[36, 37]

It appears to me that the phenomena I have revealed are such as to suggest a thorough and rewarding reappraisal, on the experimental and theoretical planes, of the findings made as the outcome of the various experiments mentioned above. The lunar and solar components revealed would indeed have remained undetectable if we had not carried out continuous observations, and the temptation would have been great to ascribe the differences observed to simple accidental disturbances, as was the case, for instance, in the interpretation given to the results of Miller by his critics.[38]

I must insist once more on the remarkable abnormalities mentioned by J. Vignal.[39] Leveling operations revealed systematic errors having to do with the direction in which the work progressed. These systematic errors behave as accidental errors as soon as series of stretches over a few tens of kilometers in length are considered. They doubtless bear a close relationship to the results obtained by Miller.

I believe the same applies to the systematic lateral refraction errors observed in triangulation operations.

From all these data it would appear, in my opinion, to be of the greatest interest to carry out the various mechanical and optical experiments mentioned above with the utmost care, with all the accuracy which the equipment now available can provide, and with *continuous* observations over a period of at least a month. In such a case, it would seem likely if not actually certain, that we should note, in the phenomena so observed, some periodic influences which are entirely similar to those I believe I have revealed in the case of the paraconical

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pendulum.[40, 41] These simple observations, which unfortunately cannot be developed in detail here, appear to throw the fullest light on the scientific interest of my findings.

(D) Significance of the Abnormalities Discovered

From our examination of the abnormalities mentioned and the discussion of the accuracy with which the principles of mechanics have been verified, it is plain that these principles do not have, by any means, the absolute value which an all too prevalent body of opinion appears to ascribe to them. These principles have acquired a sort of metaphysical quality which places them above the realm of discussion. In reality, mechanics is not at all a perfect science, a pure science in which we have nothing else to find. It is, and remains, an experimental science which can and should be improved.

The time has come, indeed, when one should go over all these phenomena once again. This re-examination manifestly seems to be of considerable interest for the development of a unified theory which could embrace, in one synthesis, the theories of gravitation, electromagnetism, and quanta. It is not at all the same thing to state

$$\Delta G + 4\pi\mu d = 0 \qquad (1)$$

or to state

$$\Delta G + 4\pi\mu d(1 + \epsilon) = 0 \qquad (2)$$

where

$$|\epsilon| \leqslant 5 \times 10^{-6}$$

in which G is the Newtonian potential, d the density, and μ the constant of universal gravitation.

Whoever has worked on these difficult questions knows that Eq. (1) cannot be substituted for Eq. (2) without a considerable measure of danger for, in the integration of partial derivative equations, the corrective terms are very important. Thus, at a time when the development of a consistent unified theory of physics might appear to offer more difficulty than ever before, an examination in depth, on the experimental and theoretical planes, of all the abnormalities mentioned above strikes me as being of the greatest interest; for it appears to be of such a type as to call for the revision of some postulates, the rigorous validity of which was accepted without true experimental support.

Facts alone must guide us, rather than mummified principles, even though they may be most useful for a first approximation. We learn only through experiment, and any thought which permanently withdraws into a set of abstract principles thus sentences itself automatically to a form of sclerosis.

Conclusions

The whole set of data given in Parts I and II seems to me to lend itself to the following summary:

(1) The motion of the paraconical pendulum using an anisotropic support is made up of periodic components having a significant statistical amplitude, of the order of the Foucault effect, with periods in the vicinity of 24 and 25 hours.

(2) These periodic components cannot be identified with those due to the gravitational effect of the moon and sun, such as they may be computed from the double principle of inertia and of universal attraction, for those are approximately one hundred million times smaller.

(3) The very peculiar periodic structure of the phenomena observed, being due to the relative importance of the wave having a period of about 25 hours, rules out any explanation based on one of the already known periodic phenomena which had been taken into consideration as possible explanations for the periodic nature of the phenomena.

In the present status of the discussion, the abnormalities observed can be accounted for only by considering the existence of a new field—namely, by envisioning the existence of complementary terms which until now had remained unnoticed.

(4) The effects observed, the order of magnitude of which is about a few millionths of gravity, are not actually incompatible with any of the earlier experimental findings for the accuracy with which these results have been obtained does not exceed a few millionths.

(5) The abnormalities noted are not isolated. Many abnormalities have been observed by other workers in a number of geophysical phenomena, and it seems likely, if not certain, that they are derived from one and the same cause.

(*A Complementary Note on Professor Allais' work will be published in the November issue.*)

Notes

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[16] *Set of Scientific Works of Léon Foucault*, Gauthier Villars, Paris, 1878, p. 386.

[17] Haringx and Suchtelen, Philips Technical Rev., 19, 1957–1958, pp. 248–254.

[18] The reader also will find a number of interesting references in Hagen, *op. cit.*, Second Part; and in Wolf, C., *Bibliographie du Pendule (1629–1885)—A Set of Memoranda Published by the French Society of Physics, Vol. IV, Papers on the Pendulum*, Gauthier Villars, Paris, 1889, pp. B1–B216.

[19] For instance, the western coasts of the continents, all other things being equal, are subject to far higher tides than the eastern coasts.

Similarly, the full tide does not coincide with the passage of the moon at the meridian, but rather follows it by about 3 hours. At the syzygies and quadratures, the maximum or minimum tide is encountered only a day and a half after that of the relevant syzygy or quadrature. This happens anywhere on the earth. It is to be noted that these two phase shifts are *very different* although the solar force is no more than a fraction of the lunar

force. It should also be underscored that the delay is the same at the quadratures, where the solar action, instead of being added to that of the moon as it is at the syzygies, is deducted from it.

Let us further point out that no satisfactory theory of marine currents has been given as yet, although some of their characteristics are very remarkable, such, for instance, as the preponderance of an easterly trend.

It is not without interest to note that mechanical effects of the tides are relatively large when compared to the tide-inducing forces due to the moon and sun, which cause them and which represent, at most, the following fractions

$$2\,(M_l/M_t)(r_t^3/d_l^3) = 11.2 \times 10^{-8}$$
$$2\,(M_s/M_t)(r_t^3/d_s^2) = 5.18 \times 10^{-8}$$

of the gravity.

This abnormality has been accounted for by mentioning the possibility of oceanic areas of resonance, but this assumption, quite plainly, is entirely gratuitous.

[20] Hagen, *op. cit.*, p. 24. See also Inst. Géo. Nat., *Report on Control Measurements of the Eiffel Tower Stability (1893–1951)*, May 1, 1952.

[21] Hagen, *op. cit.*, pp. 22–40.

[22] *Ibid.*, pp. 110, 111.

[23] *Ibid.*, pp. 94–96.

[24] *Ibid.*, pp. 142–147. See also the second appendix to this work, pp. 36, 37, and 46.

[25] *Ibid.*, pp. 166, 167.

[26] The objection has been raised that the experimental equipment used by Gen. Louis Pasteur could not be viewed with any degree of confidence. I must stress that his pendulums start only in the east–west direction and in the presence of some close obstacles arranged in a certain fashion. This rules out a great many hypotheses. (In the same sense, see the results obtained by Victor Panisetti, Cosmos, 1856, p. 503.)

[27] These numerous characteristics cannot be due to chance. The reader is referred to Gaussen, C.R.A.S., 90, 1880, p. 518; Gaussen, C.R.A.S., 90, 1880, p. 593; Belot, C.R.A.S., 143, 1906, p. 1126; Belot, C.R.A.S., April, 1907, p. 885; Delauney, *Lois des distances des satellites du soleil*, Gauthier Villars, Paris, 1909; Butavand, *Les lois empiriques du système solaire*, Gauthier Villars, Paris, 1913; Ollive, F., C.R.A.S., 157, 1913, p. 1501; Blagg, M. A., Roy. Astr. Soc., 73, 1913, p. 414; Demozay, *Relations remarquables entre les éléments du système solaire*, Gauthier Villars, Paris, 1919; Delauney, *Problèmes Astronomiques*, Gauthier Villars, Paris, 1920; Vilar, *Notes sur les distances des planètes au soleil*, Jouve, Paris, 1923; Bourgeois and Cox, C.R.A.S., 198, 1934, p. 53.

[28] The reason mentioned in this case is about equivalent to the "sleep-inducing virtue" of opium as mentioned in Molière's play!

[29] Majorana, C.R.A.S., 173, 1921, p. 478; Journ. de Phys. et Rad., I, 1930, pp. 314–324; Phil. Mag. XXXIX, 1920, pp. 488–504; Schlomka, Zeit. für Geophys., 1927, p. 397.

[30] Cremieu, C.R.A.S., December, 1906, p. 887; Rev. Gén. Sc. Pur. et Appl., 18, 1907, pp. 7–13. According to Cremieu, everything takes place as though gravitation measured in water were greater than that computed by means of the theory of attraction from a distance, the difference being about 1/10. Therefore, it is a *considerable* difference.

[31] In other words, if, to the Newtonian effects, we added actions 10^{-6} times smaller and which would have a zero value on an average during the revolution of the planet, these would probably stay unrevealed.

[32] One should read, in particular, the remarkable paper by Miller, *The Ether Drift Experiment and the Determination of the Absolute Motion of the Earth*, Rev. of Mod. Phys., 1933, p. 203, the findings of which—derived from 200,000 observations—are remarkably consistent; the proceedings of the Mount Wilson Conference of 1927, The Astrophysical Journal, 1928, p. 341. One should also consult the references given by Miller at the end of his paper. It is startling that the findings published in this paper should have been ignored for 25 years. The outright pigeonholing of Miller's paper strikes me as one of the scandals of contemporary physics.

[33] *Sur l'existence d'une dissymétrie optique de l'espace*, Journ. des Obs. XI, pp. 49–63. Here again, the internal consistency of the results obtained goes beyond any and all doubt. By the same author, *La dissymétrie de l'espace sidéral et le phénomène des marées*, C.R.A.S., 183, 1926, pp. 116–118; *Sur la dissymétrie mecanique et optique de l'espace en rapport avec le mouvement absolu de la terre*, C.R.A.S., 1926, pp. 921–923.

It has been possible to relate satisfactorily the results obtained by Miller and Esclangon (see Carvallo, E., *Vitesse de la terre mesurée par des expériences purement terrestres*, C.R.A.S., 1934, p. 247; *Vitesse de la terre et Relativité*, Rev. Scientif., 1934, pp. 405–410; *Les lois absolues de la lumière et la loi de relativité*, Rev. gén. Electricité, XXIX, pp. 493–546). The results obtained by Esclangon at Strasbourg have not been found again in Paris (C.R.A.S., 1935, p. 1165), *but the experimental setup was not the same.*

[34] Ann. de Chim. et Phys., 1860, p. 129.

[35] Mesures, 1937, No. 11, pp. 13–17, and No. 12, pp. 19–21.

[36] There is no doubt, in our view, that the phenomena which I have revealed are such as to support Miller's papers indirectly in such a way as to confirm their validity. The very bases of the theory of relativity thus could again come under scrutiny.

[37] That some of the experimenters (A. Piccard and E. Stahel, Georg Joos for the Miller effect, B. Strasser, D. B. Brace for the Fizeau effect) should not have found the same results is perfectly accounted for, in our opinion, by the fact that, at some time, the total lunar and solar effect, as actually noted in the case of the paraconical pendulum, is very small (Piccard and Stahel, Journ. Phys. IX, 1928, pp. 49–60; C.R.A.S., 185, 1927; Joos, Ann. der Phys., 1930, pp. 385–407; Strasser, Ann. der Phys., 24, 1907, pp. 137–144; Brace, Phil. Mag., 1904, pp. 317–329; Phil. Mag., 1905, pp. 591–599).

As a matter of fact, no parallel can be drawn between the Piccard and Stahel experiments carried out from a baloon and the 200,000 observations by Miller carried out in a very well organized laboratory, with every possible precaution (see Brylinski, etc., C.R.A.S., 185, 1927, p. 1198). Finally, the experiments carried out by Esclangon reveal that some small modifications in the equipment, which are of no apparent significance, might cause a cessation of the effects observed (see footnote 33 above).

[38] See, in particular, R. S. Shankland, S. W. McCuskey, F. C, Leone, and G. Kuersi, Rev. of Mod. Phys., 27, 1955, pp. 167–178. and the appended references. The authors ascribe the effects obtained by Miller to the conjugate effect of random disturbances and temperature disturbances. However, this criticism does not account for the extraordinary consistency of Miller's results with the motion of the earth about the sun (see Figs. 23 and 28 of his paper, pp. 232, 237). Similarly, it does not account for the remarkable adjustments with phases which agree with sidereal time, as shown on p. 235 of his work. It also leaves out the agreement between Miller's and Esclangon's results (see the papers by Carvallo already mentioned in footnote 33 above).

[39] *Evaluation of the Accuracy of the Leveling Method*, Bull. Géod., 53, 1936, and *Precision Leveling*, Publ. de l'Inst. Géog. Nat., Paris, 1948.

[40] The fact that the abnormalities noted in most of the phenomena mentioned are distributed according to the normal law cannot by any means be interpreted by ascribing the effect to an accidental cause. I was thus able to note that the sum of the eleven sine curves obtained in the analysis of my numerical series by the method of the least squares is distributed according to *the normal law*. Yet we are dealing indeed with eleven sine curves, thus with a periodic magnitude. The random aspect of a numerical series does not by any means thus rule out the possibility that it may represent a periodic phenomenon.

[41] A remarkable fact is that the relative order of magnitude of the different departures noted (whether we are dealing with Miller effects, systematic errors related to the leveling or triangulation operations, abnormalities in the fall of bodies, or again abnormalities in the motions of the paraconical pendulum) always remains the same—namely, 5×10^{-6}. Everything happens as though all these phenomena had one and the same cause.

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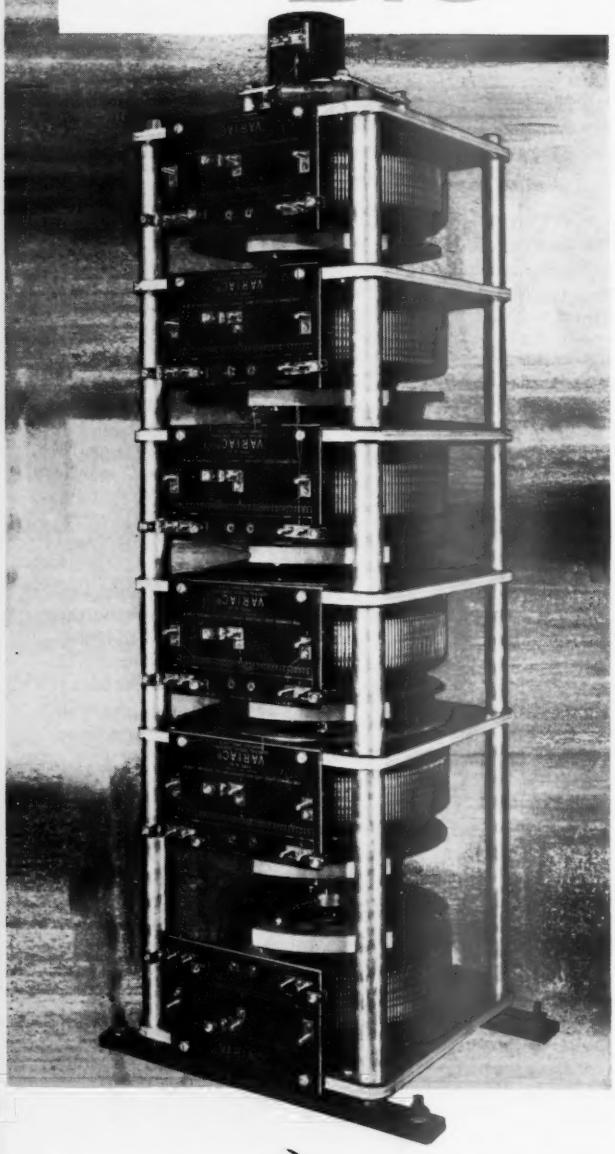

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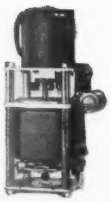

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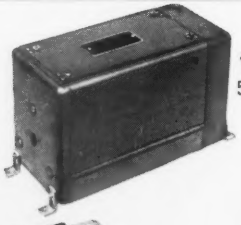

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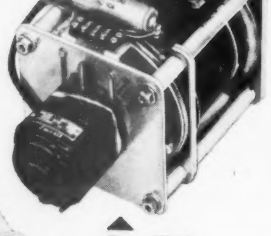

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Acoustics, Sound, Noise

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Aerothermochemistry, Dissociation, Ablation

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Air Transportation

Special Issue: Tenth Annual Local Air Service Section. *Flight*, June, 1959, pp. 51–88. *Partial*

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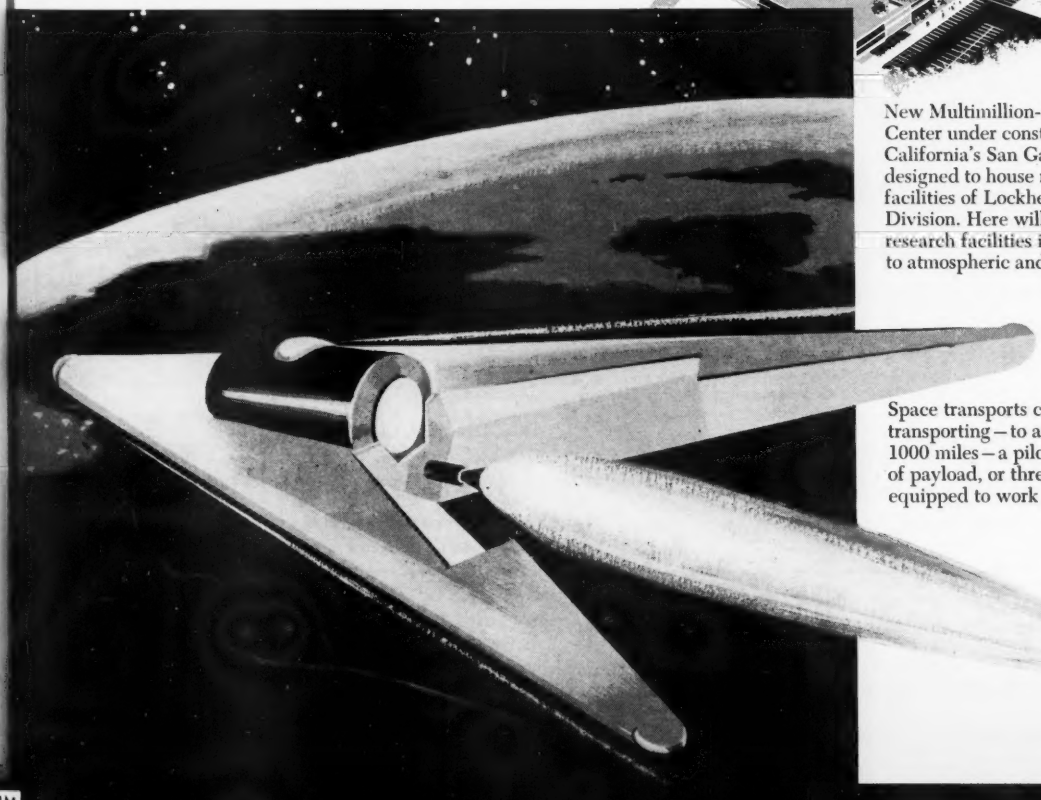

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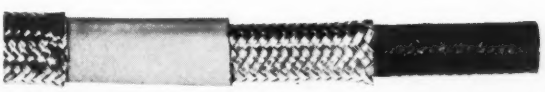

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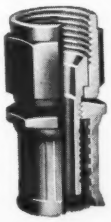

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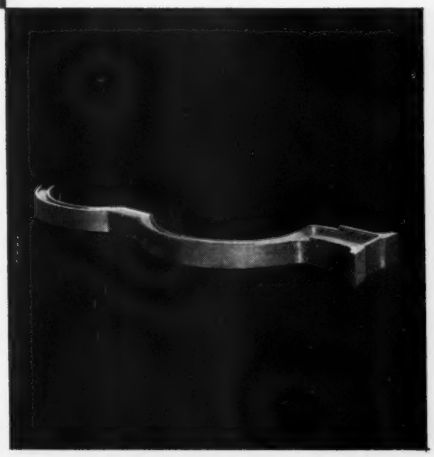

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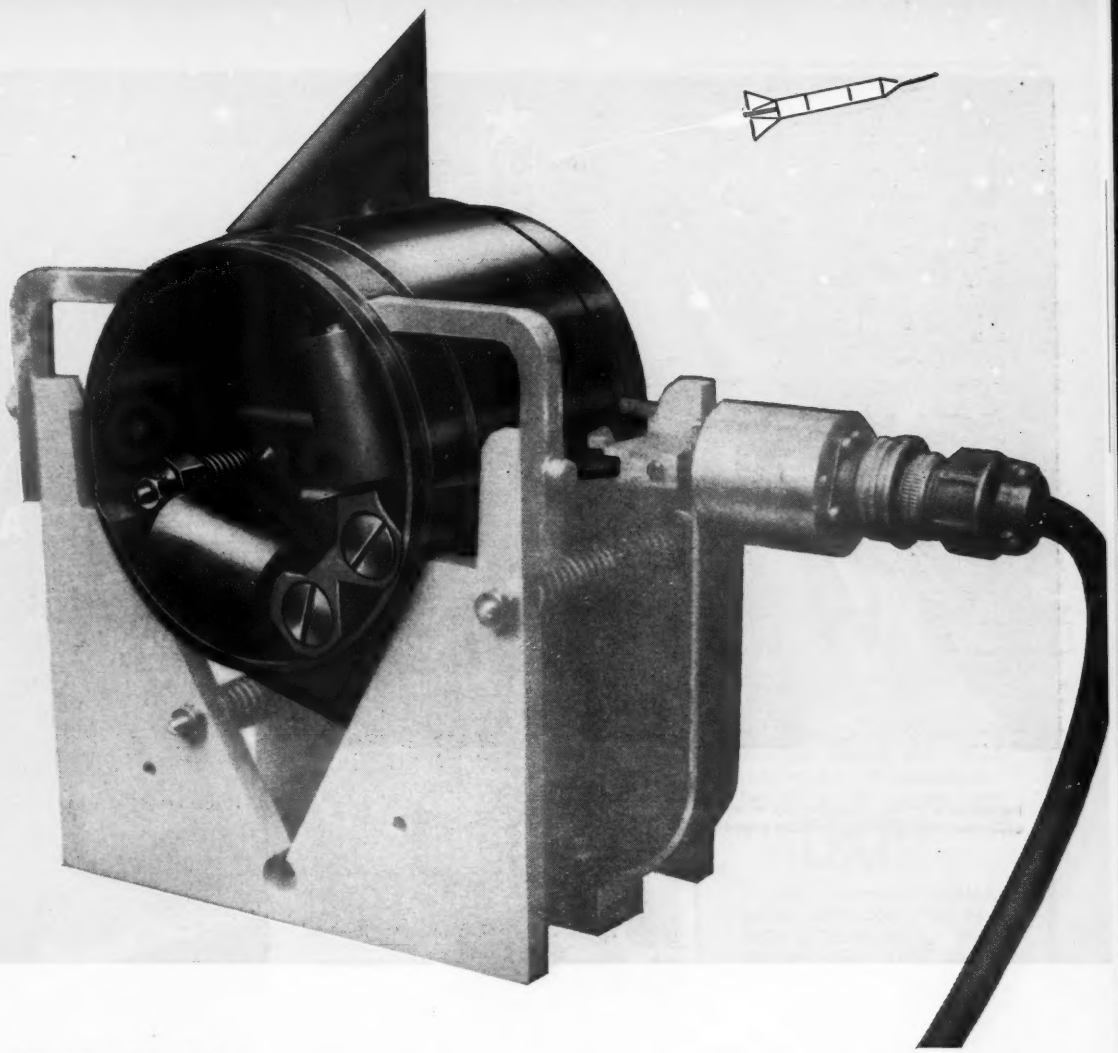

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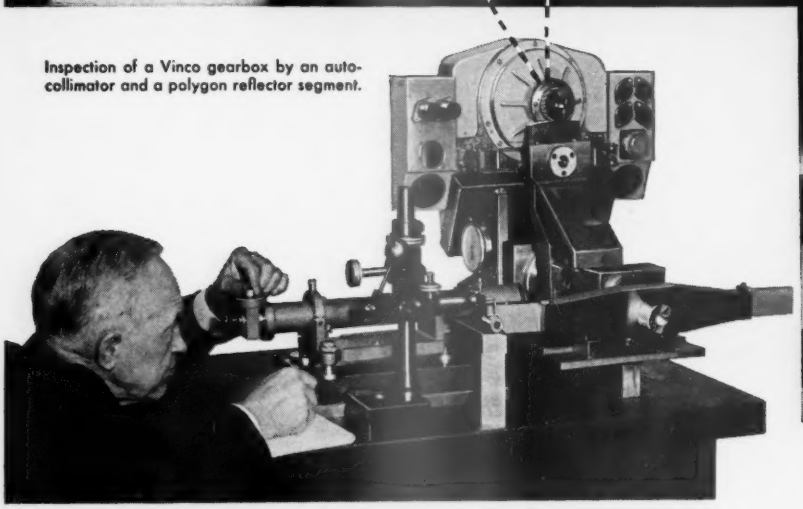

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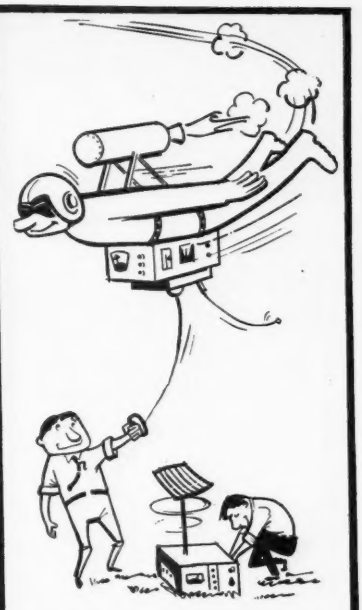

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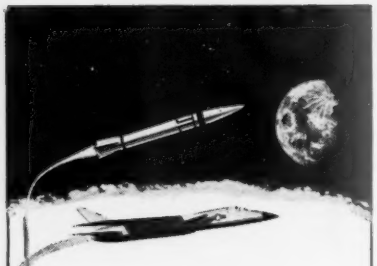

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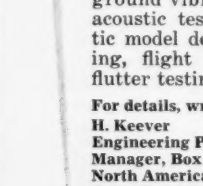

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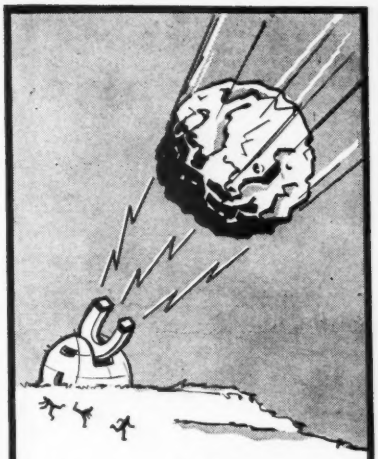

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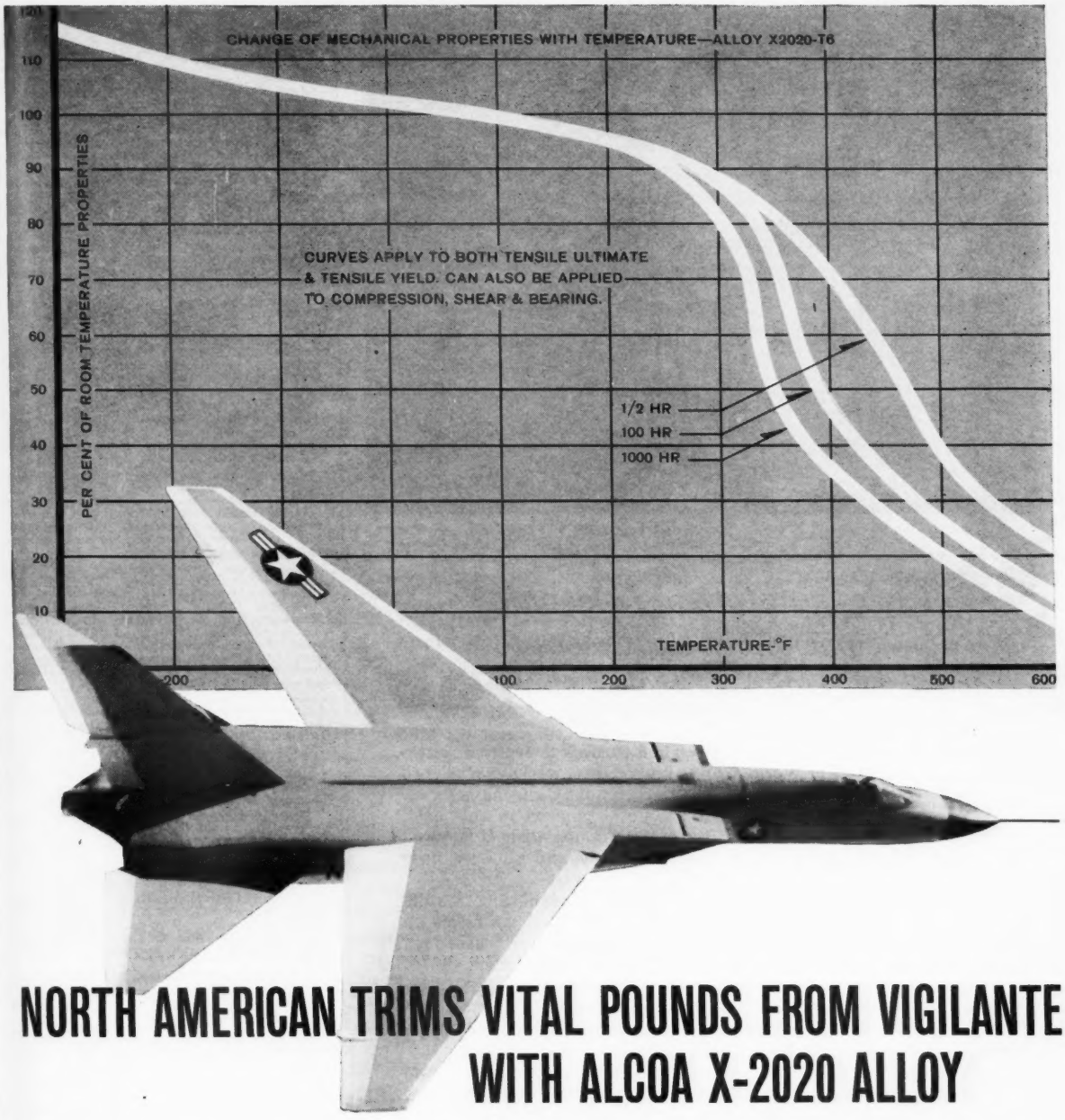

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Determining Lunar Mission Guidance Requirements. B. M. Rosen. *Sperry Eng. Rev.,* June, 1959, pp. 27–33. Analysis of determining factors covering the following aspects: trajectories to the moon, cutoff speed, path angle, orientation, altitude, midcourse corrections, guidance systems, and interplanetary missions.

Steady-State Circular Pitching and Yawing Motion of Symmetric Missiles. Ch. H. Murphy, Jr. *J. Aero/Space Sci.,* Sept., 1959, pp. 600, 601.

Infrared Missile Homing Proves Simplest, Most Accurate. W. J. Haywood, Jr. *Space/Aeronautics,* Aug., 1959, pp. 131–133. Discussion of the basic principles of infrared guidance of homing-type missiles. Parameters that must be detected by IR sensors are shown as well as tracking loop requirements.

A Review of the Current Status of Satellite Attitude Control. R. E. Roberson. (*IAS-ARS Reg. Meeting Space Expl., San Diego, Aug. 5, 1958.*) *J. Astron. Sci.,* Summer, 1959, pp. 25–30. 36 refs. Summary and discussion of the major aspects of satellite attitude control including general descriptions, first principles, and control devices. The status of each area is examined and problems requiring future work are indicated.

Hydraulics Packs Power for Missile Erection. G. D. Shaw. *Space/Aeronautics,* Aug., 1959, pp. 77–80, 82. Discussion of general requirements and methods for mechanically handling large missiles. Application is made to the hydraulic system design for a Polaris test erector.

Switching Circuits for Missile Count-Downs. D. W. Boensel. *Electronics,* July 31, 1959, pp. 76–78. Description of a transistorized, level-sensitive switch using nonlinear negative feedback to provide stable operation for go-no-go signals.

Development of a Modern ICBM. *Interavia,* July, 1959, pp. 812–816. Description of the testing facilities and procedures during the production of the Martin Titan.

Manned Space Station Needs Special "Ferries and Tugs." III. S. B. Kramer and R. A. Byers. (*AAS Natl. Meeting, Wash., Dec. 27–30, 1958.*) *Space/Aeronautics,* Aug., 1959, pp. 61–63. Description of the preliminary design of a re-entry vehicle and "astrotug." Details on structures and subsystems are given with emphasis on propulsion systems. Weight breakdowns are presented for both vehicles.

Explorer Rocket Research Program. G. Robillard. (*ARS 13th Annual Meeting, New York, Nov. 17–21, 1958.*) *ARS J.,* July, 1959, pp. 492–496. Discussion of the experimental launching of Jupiter- and Explorer-type missiles, including such aspects as design, firing sequence, payload and orbits, as well as scientific data on cosmic radiation.

The Orbital Post Office. Sidney Metzger. (*ARS 13th Annual Meeting, New York, Nov. 17–21, 1958.*) *Astronautics,* Aug., 1959, pp. 38, 39, 48, 50. Discussion of a satellite two-way microwave frequency circuit and of photoelectric transcribing and printing devices for the intercontinental transmission of facsimile letters.

A Photogrammetric Radio Telescope Calibration. D. L. Ockert. (*Am. Soc. Photogrammetry, 25th Annual Meeting, Wash., Mar. 10, 1959.*) *Photogrammetric Eng.,* June, 1959, pp. 386–395. Study of the feasibility of two methods for calibrating a 40-ft. radio telescope.

Precision Photogrammetry in Missile Testing. D. C. Brown. (*Am. Soc. Photogrammetry, 25th Annual Meeting, Wash., Mar. 10, 1959.*) *Photogrammetric Eng.,* June, 1959, pp. 372–376. Description of ballistic cameras employed in the Atlantic Missile Range and of the operational procedures and reasons for their use.

(*Continued on page 94*)

XUM

INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

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ACOUSTICS, SOUND, NOISE

A STUDY OF THE ACOUSTIC FATIGUE CHARACTERISTICS OF SOME FLAT AND CURVED ALUMINUM PANELS EXPOSED TO RANDOM AND DISCRETE NOISE. Appendix A - PANEL NATURAL FREQUENCIES. Appendix B - PRESSURE CORRELATION STUDY. R. W. Hess, R. W. Herr, and W. H. Mayes. US, NASA TN D-1, Aug., 1959. 41 pp. 12 refs. Determination of the fatigue-life of simple 2024-T3 aluminum alloy panels exposed to both discrete-frequency noise from a siren and random noise from an air jet. No significant differences were noted in the nature of failures experienced for two types of loadings. At a given root-mean-square stress level, the failure times were generally shorter for the random loading than for the discrete-frequency loading. These differences in failure times were noted to be a function of stress level, the larger differences occurring at the lower stress levels. Increases in time to failure were obtained as a result of increased panel thickness, increased panel curvature, and particularly for increased static-pressure differential across curved panels.

AERODYNAMICS, FLUID MECHANICS

Aerothermochemistry, Dissociation, Ablation

SHIELDING STAGNATION SURFACES OF FINITE CATALYTIC ACTIVITY BY AIR INJECTION IN HYPERSONIC FLIGHT. P. M. Chung. US, NASA TN D-27, Aug., 1959. 20 pp. 11 refs. Study of the effect of air injection in shielding stagnation surfaces having various finite catalytic activities from the aerodynamic heating in hypersonic flight. Only the case of chemically frozen boundary layer is considered. A set of closed-form solutions is obtained and can be used to calculate the heat-transfer rate when the blowing rate and the catalytic characteristics of the surface material are given. It is found that air injection can strongly influence the heat acceptance rate of a catalytic surface and can thus be used to control the heat input to surfaces on which catalytic activity varies widely with temperature and flight conditions.

INVESTIGATION OF ATOMIC-OXYGEN RECOMBINATION RATES. C. B. Kretschmer. Aerojet-Gen. Rep. 1611 (AFOSR TR 59-62) [AD 217008], May, 1959. 35 pp. 23 refs. Investigation of the kinetics of the recombination of oxygen atoms and the determination of the feasibility of using the atomic oxygen in the upper atmosphere as a source of energy for propulsion. Rate reactions (k_1 and k_2) are found for several possible combinations. The values found for k_1, and the relative efficiencies of argon, molecular oxygen, and atomic oxygen are consistent with recent shock-tube determinations.

VARIATIONAL THEORY OF DISSOCIATION AND RECOMBINATION. J. C. Keck. Avco Everett Res. Lab. Res. Rep. 58 (AFBMD TR 59-4), June, 1959. 6 pp. Presentation of a variational theory that gives an upper bound to the rate of recombination and dissociation of diatoms in the presence of a third particle. It involves the introduction of a trial surface in phase space which divides the "free" and "bound" states with which an upper bound to the reaction rate may be calculated. The parameters defining the "trial" surface are then varied to obtain a least upper bound. The theory is absolute in the sense that it contains no free parameters other than those describing the interaction potential. The general principles of the theory are also applicable to bounds for other chemical and physical rate processes.

METEORIC ABLATION THROUGH INTERFACIAL INSTABILITY. Sin-I Cheng. ARS J., Aug., 1959, pp. 579-587. Analysis of interfacial instability of the Taylor type on the surface of a meteoric body. The presence of a component of the effective gravity field tangent to the gas-liquid interface considerably increases the seriousness of the instability, especially in the region of the transonic shoulder. In the transonic region, the logarithmic increment per sec. of the most

critical component of initial disturbance is likely to be significantly larger than that in the stagnation region where the normal component alone acts. The value of this logarithmic increment at a given location is inversely proportional to the local value of the kinematic viscosity of the liquid at the surface.

RADIATIVE TRANSPORT WITHIN AN ABLATING BODY. L. P. Kadanoff. Avco Everett Res. Lab. Res. Rep. 61 (AFBMD TN 59-12), July, 1959. 37 pp. Development of a method for calculating the net radiative flux and temperature distribution within a semi-infinite body which emits, absorbs, and scatters radiation and allows some radiation to escape from its surface. Application is made to the problem of calculating temperature distribution within bodies in steady state ablation. Also, simple formulas are presented for predicting the temperature distribution in the "liquid layer" of a glassy ablating body. A simple relation between the ablation rate and the emissivity of a body in steady state ablation is given. The concept of effective conductivity is extended to scattering media. However, since this concept fails near a boundary, the effective conductivity concept gives completely wrong answers for the temperature distribution in the liquid layer.

Aerothermodynamics

THE GROWTH OF THE THERMAL BOUNDARY LAYER IN LAMINAR FLOW BETWEEN PARALLEL FLAT PLATES. A. McD. Mercer. Appl. Sci. Res., Sect. A, No. 5, 1959, pp. 357-365. 10 refs. Presentation of solutions for the heat transfer at the inlet of a parallel plate channel. Instead of separating variables, the energy equation is solved, after transformation, in the form of a power series. This method supplies information concerning the initial glowth of the thermal boundary layer which is not obtainable by previous methods using eigenfunction expansions. A sufficient number of coefficients of the series is computed to allow the present solution to be joined to the asymptotic eigenfunction solution, thus completing the treatment of the problem for all values of the longitudinal variable.

EXPERIMENTAL INVESTIGATION OF LAMINAR HEAT TRANSFER WITH NONUNIFORM SURFACE TEMPERATURE AT M = 4.3. D. G. DeCoursin, R. E. Larson, and N. C. Helm. USAF WADC TR 59-285 [AD 216300], Jan., 1959. 60 pp. 19 refs. Measurement of local heat transfer in a laminar boundary layer on a 20° total included angle cone in a M = 5 stream. The data are correlated with Lighthill's theory transformed to cone flow by the Mangler transformation. In applying the theory, the temperature distributions are approximated by linear segments. The agreement between theory and experiment is about ± 10%.

RASCHET TEPLOOBMENA I TRENIIA PLOSKOI PLASTINY, OBDUVAEMOI SVERKHZVUKOVYM POTOKOM, PRI NALICHII PORISTOGO PODVODA GAZA I SUBLIMATSII V USLOVIIAKH LAMINARNOGO POGRANICHNOGO SLOIA. V. P. Motulevich. AN SSSR Otd. Tekh. Nauk Izv. Energ. i Avtom., Jan.-Feb., 1959, pp. 33-38. In Russian. Calculation of heat transfer and friction for a flat plate in supersonic flow with porous injection into the laminar boundary layer. The distribution of friction forces and heat fluxes along the surface of the plate is calculated; the temperature of the plate is assumed to be constant. The physical gas parameters and their derivatives are assumed to be known experimentally or on the basis of the molecular kinetic theory, and no limitations are imposed in relation to their temperature dependence. The thickness of the thermal and dynamic layers is taken as variable, and the problem is solved by means of the finite-thickness boundary-layer theory. The method of calculation is given in detail and covers such cases as the evaporation of a body, cooling, and the problem of an axisymmetric body.

EXPERIMENTAL INVESTIGATION OF AIR FILM COOLING APPLIED TO AN ADIABATIC WALL BY MEANS OF AN AXIALLY DISCHARGING SLOT. S. S. Papell and A. M. Trout. US, NASA TN D-9, Aug., 1959. 64 pp. Study of the characteristics of axially discharging single-slot film cooling of an adiabatic wall exposed to a hot air stream. The mainstream gas temperature ranges from 520° to 2,000° R. and the Mach Number is varied from 0.15 to 0.70, with cooling-air temperatures varying from 540° to 870° R. and cooling-air Mach Number from 0.0 to 1.0. A data correlation covering the range of effective temperature ratios from 0.1 to 1.0 is obtained using four variations of a basic equation, and it is found that the independent variation of mainstream Mach Number has very little effect on film cooling performance. Basic film-cooling data plots are presented in nondimensional form.

Boundary Layer

OB INTEGRIROVANII URAVNENII POGRANICHNOGO SLOIA. V. Ia. Shkadov. AN SSSR Dokl., June 1, 1959, pp. 730-732. In Russian. Development of a method used to reduce the calculation of boundary layers, described by partial nonlinear differential equations, to the solution of boundary problems for ordinary, linear, differential equations. The determined functions are independent from the pressure gradient and can be calculated for any type of profile. In the case of compressible flow, these functions depend upon the physical properties of the gas and the boundary conditions for the temperature of the profile.

K TEORII TECHENIIA GAZA V SLOE MEZHDU POVERKHNOST'IU UDARNOI VOLNY I PRITUPLENNOI POVERKHNOST'IU TELA VRASHCHENIIA. N. A. Slezkin. AN SSSR Otd. Tekh. Nauk Izv. Mekh. i Mashinostr., Mar.-Apr., 1959, pp. 3-12. In Russian. Study of the flow of gas in the layer located between the shock wave front and the blunt surface of the body of revolution. Two approaches are used in the investigation: (1) the flow region should be separated not only in the longitudinal direction, isolating the laminar sublayer, the tur-

bulent layer, and the external flow region, but also transversally, isolating the separate sectors of the layer - (a) the Reynolds layer, (b) the Oseen layer, and (c) the Prandtl layer; (2) the method of successive approximation is applied to study the development of the phenomenon within the bounds of separate sectors of the layer with transition, thus allowing the application of linearized equations.

SOLUTIONS OF THE LAMINAR COMPRESSIBLE BOUNDARY-LAYER EQUATIONS WITH TRANSPIRATION WHICH ARE APPLICABLE TO THE STAGNATION REGIONS OF AXISYMMETRIC BLUNT BODIES. J. T. Howe and W. A. Mersman. US, NASA TN D-12, Aug., 1959. 73 pp. Presentation of 15 solutions of the laminar compressible boundary layer equations for various wall-temperature levels and transpiration rates. The solutions are obtained in the Brown and Donoughe form for a Euler Number of 1/3 and a Prandtl Number at the wall equal to 0.7. Application to the stagnation region of axisymmetric bodies can be made by means of the Mangler transformation.

LOW-SPEED WIND-TUNNEL INVESTIGATION OF BLOWING BOUNDARY-LAYER CONTROL ON LEADING- AND TRAILING-EDGE FLAPS OF A FULL-SCALE, LOW-ASPECT-RATIO, 42° SWEPT-WING AIRPLANE CONFIGURATION. R. L. Maki and D. J. Giulianetti. US, NASA TN D-16, Aug., 1959. 29 pp. Presentation of lift, drag, pitching-moment, and rolling-moment data for an angle of attack range from -8° through stall. Leading-edge flap deflections up to 40° without BLC resulted in increases in maximum lift because flow separation at the wing leading edge was delayed to higher angles of attack. For deflections greater than 40°, moderate amounts of leading-edge blowing BLC were required to prevent the flow from separating over the flap knee; with BLC applied, maximum lift continued to increase with increasing flap deflection up to 60°. Double-droop and single-droop leading edge flaps were compared with or without BLC. In no case was double droop significantly more effective than single droop. Some effects of plugs in the trailing-edge nozzle on lift and roll control with flaps differentially deflected as ailerons are presented.

UNSTEADY LAMINAR COMPRESSIBLE BOUNDARY LAYERS ON AN INFINITE PLATE WITH SUCTION OR INJECTION. Kwang-Tzu Yang. J. Aero/Space Sci., Oct., 1959, pp. 653-662. 12 refs. Investigation of unsteady compressible laminar boundary layers on an infinitely extended porous plate. An integral solution, based on two types of assumed velocity and temperature profiles, is presented for the general case where the unsteady free-stream velocity and rate of surface suction or injection are both arbitrary, and an exact solution for certain specific unsteady free-stream and surface suction or injection variations is given. Finally, several general qualitative conclusions of the unsteady effects of free-stream velocity and surface suction or injection on laminar boundary-layer behavior are made.

THE EFFECT OF FREE-STREAM OSCILLATIONS ON THE LAMINAR BOUNDARY LAYERS ON A FLAT PLATE. R. J. Nickerson. USAF WADC TR 57-481 [AD 210477], Dec., 1958. 86 pp. 27 refs. Analysis of the effect of harmonic oscillations in the magnitude of the free-stream velocity on the laminar velocity and temperature boundary layers. It predicts a negligible change in the steady rate of heat transfer from the plate surface, and shows that, for large enough values of a dimensionless variable, the flow pattern is a simple superposition of the steady flow plus the oscillating flow. Experimental velocity profiles obtained with a hot-wire anemometer are presented and show reasonably good agreement with the theory. Heat transfer measurements indicate no change in the steady rate of heat transfer for frequencies up to 10 cps and amplitudes of oscillation of about 25%.

Control Surfaces

SOME DATA ON ELEVATOR DAMPING AND STIFFNESS DERIVATIVES ON A DELTA WING AIRCRAFT MODEL AT SUPERSONIC SPEEDS. K. J. Orlik-Rückemann. Canada, NRC Aero. Rep. LR-250, June, 1959. 11 pp. Presentation of results obtained by means of an electromagnetically excited apparatus in free oscillation tests on small aerodynamic surfaces. The elevator hinge moment derivatives on a half model of a delta wing aircraft are determined and the results compared with theory. In case of stiffness derivatives, the results are compared with data obtained in static experiments.

Flow of Fluids

APPLICATION OF A RECIPROCAL PROPERTY TO SUBSONIC FLOW. G. Power and P. Smith. Appl. Sci. Res., Sect. A, No. 5, 1959, pp. 386-392. Discussion of a reciprocal property for the two-dimensional flow of a compressible fluid having simply related velocity potentials and stream functions. It is found that a certain pressure density law corresponds to each flow pattern, and, using this property, an approximation method for subsonic flow is deduced and an example given.

PRIMER PLOSKO-PARALLEL'NOGO OKOLOZVUKOVOGO TECHENIIA GAZA S ISKRIVLENNYM SKACHKOM UPLOTNENIIA, OKANCHIVAIUSHCHIMSIA VNUTRI TECHENIIA S FUNKTSIEI TOKA VIDA $\Psi_{y_3} = \rho^{y_3} f_{y_3}(\frac{\theta}{\rho})$. I. Biibosunov. AN SSSR Dokl., June 11, 1959, pp. 951-954. In Russian. Study covering the problem of a plane-parallel sonic flow of gas with an abrupt curved density transition from supersonic to subsonic velocity. The form of the stream function in the specified sector of the flow is given, and the process of calculation is described in detail.

ON THE UNIQUENESS OF COMPRESSIBLE FLUID MOTIONS. James Serrin. Arch. Rational Mech. & Anal., No. 3, 1959, pp. 271-288. 17 refs. Analysis of the initial value problem for compres-

sible viscous and nonviscous fluid flows and the uniqueness of its solutions. It is found that the fluid motion in a bounded region is uniquely determined by its initial velocity, temperature, and density distribution, together with certain boundary conditions.

ON A SINGULAR POINT IN THE NEWTONIAN THEORY OF HYPERSONIC FLOW. N. C. Freeman. Princeton U. Dept. Aero. Eng. Rep. 466 (AFOSR TN 59-635), May, 1959. 28 pp. 10 refs. Analysis of hypersonic flow past a sphere in the neighborhood of the singular point which occurs at $\theta = 60^{\circ}$. A uniformly valid theory is developed which exhibits the limiting detached "free layer" behavior postulated by Hayes and Lighthill in the limit as the ratio of specific heats $\gamma \to 1$. The result indicates that the curvature of the streamline relative to the body is the most important factor in this region. A discussion is given on the empirical modified Newtonian theory of Lees as a good approximation to experimentally determined pressure distributions.

ON THE NEWTONIAN THEORY OF HYPERSONIC FLOW FOR A BLUNT BODY. N. C. Freeman. Princeton U. Dept. Aero. Eng. Rep. 467 (AFOSR TN 59-634), May, 1959. 14 pp. Derivation of the Hayes-Serbin theory of Newtonian hypersonic inviscid flow past blunt bodies by a formal expansion procedure in powers of $(\gamma - 1)/(\gamma + 1)$, when γ is the ratio of specific heats. The theory is shown to be a uniformly valid extension of the Newtonian hypersonic flow past bluff bodies developed by Chester and Freeman. Particular attention is given to the solution of the flow past a sphere where the original bluff body result is shown to be valid in the neighborhood of the stagnation point.

CALCULATION OF SUPERSONIC FLOW PAST BODIES SUPPORTING SHOCK WAVES SHAPED LIKE ELLIPTIC CONES. B. R. Briggs. US, NASA TN D-24, Aug., 1959. 30 pp. 10 refs. Presentation of numerical solutions for supersonic perfect-gas flow past bodies with shock waves shaped like elliptic cones. The inverse method of solution is used, wherein the conditions at the shock wave are prescribed and the results are in the form of body shapes and surface pressure distributions. Comparisons are made with existing approximate theories and with results for circular cones.

O TELAKH VRASHCHENIIA, IMEIUSHCHIKH MINIMAL'NOE SOPROTIVLENIE NA SVERKHZVUKOVYKH SKOROSTIAKH. Iu. D. Shmyglevskii. AN SSSR Dokl., June 11, 1959, pp. 958-960. In Russian. Investigation covering the problem of bodies of revolution with minimum wave drag at supersonic speeds. Only cases involving an attached shock wave are studied. The variational problem arising in the calculation of the profile is analyzed, and the results are discussed along with those obtained previously.

STATSIONARNOE OBTEKANIE UGLA POTOKOM BESKONECHNO PROVODIASHCHEGO GAZA. G. A. Liubimov. AN SSSR Dokl., June 1, 1959, pp. 733-735. In Russian. Study of the problem of steady, infinite, conducting gas flow around a wedge for an arbitrary distribution of the magnetic field in relation to the flow. A system of cylindrical coordinates is introduced and the solutions are obtained for $\sigma = \infty$, depending only upon the coordinate of the angle φ. The case of a nonconducting wedge is covered as well as that of the infinitely conducting one.

EXPERIMENTAL INVESTIGATION AT TRANSONIC SPEEDS OF PRESSURE DISTRIBUTIONS OVER WEDGE AND CIRCULAR-ARC AIRFOIL SECTIONS AND EVALUATION OF PERFORATED-WALL INTERFERENCE. E. D. Knechtel. US, NASA TN D-15, Aug., 1959. 84 pp. 24 refs. Comparison of test results with theory to evaluate wall-interference effects. For the three sizes of single wedges with straight afterbodies, pressure distribution and drag at zero lift indicates small systematic effects of model size. Additional indications of wall interference are obtained by comparisons of experimental zero-lift pressure distributions and drag results with corresponding results from available theories for the single wedge, double-wedge, and the circular-arc airfoils. The slight but systematic differences between the experimental and theoretical pressures indicate the existence of an open-jet type of wall interference throughout the Mach Number range from 0.7 to 1.09. Good agreement with sonic theory is obtained for a circular-arc airfoil under choked flow conditions with solid test-section walls, when the data are computed for sonic speed. This tends to verify theoretical results showing that choked flow closely resembles sonic free-air flow.

NICHTANGESTELLTE ROTATIONSHALBKÖRPER MIT KLEINEM WELLENWIDERSTAND IM SCHALLNAHEN UND HÖHEREN ÜBERSCHALLGEBIET. Werner Schmidt. ZFW, July, 1959, pp. 194-201. In German. Calculation of very slender bodies of minimum wave drag (Sears-Haack bodies) in first approximation at near- sonic and higher supersonic speeds, based on relations for half-bodies of revolution. The investigation of pressure coefficients in first approximation and of the Mach Number influence in a second-order approximation shows that, in the case of bodies of finite thickness flying at higher supersonic speeds, higher-order approximations and an additional source distribution are needed in order to fulfill the boundary conditions at the body surface. A comparison of the wave drag of two bodies at low and at higher supersonic speeds indicates a decrease in drag coefficients with increasing Mach Numbers.

OBTEKANIE KOLEBLIUSHCHEISIA POVERKHNOSTI POTOKOM SIL'NO RAZREZHENNOGO GAZA. N. T. Pashchenko. Prikl. Mat. i Mekh., July-Aug., 1959, pp. 760-765. In Russian. Study of the flow of highly rarefied gas around oscillating surfaces. The total force per unit surface which, in addition to the initial, has nonstationary motions is determined as well as its projections on the corresponding direction, such as pressure and friction. A tentative definition is made of the applicability

of the method of free molecular flow around concave surfaces, and the limitations of the surface shape and motion are determined. For illustration purposes, the case of flow around an oscillating plate is studied, and it is found that the expression for the excessive pressure corresponds to the known formula of the piston theory.

ON SUPERSONIC FLOW PAST THICK AIRFOILS. Abraham Kogan. Technion Res. Devel. Found., Haifa, Final Rep. (AFOSR TR 59-64) [AD 217033], Feb., 1959. 37 pp. Study of the inviscid rotational supersonic flow behind the shock wave attached to the sharp leading edge of a 10%-thick parabolic biconvex airfoil. Using an expansion in the power series of Crocco's stream function, an iterative process is developed for the determination of pressure distribution along the airfoil surface. For the special case of a near-shock-detachment flow, a simple approximation is derived for the flow in the whole region between the airfoil and the shock wave.

EXPERIMENTAL INVESTIGATION OF TRANSONIC FLOW PAST TWO-DIMENSIONAL BICONVEX CIRCULAR-ARC AIRFOILS AT SMALL ANGLES OF ATTACK. Ryuma Kawamura and Keiichi Karashima. Tokyo U. Aero. Res. Inst. Rep. 342, Apr., 1959. 42 pp. 15 refs. Presentation of some test results for airfoils with thickness-chord ratios of 10.6, 8.08, and 5.44. Aerodynamic characteristics are analyzed from surface pressure distributions obtained by interferometry. It is found that most of these results confirm the validity of the transonic similarity rule while there are some, such as the position of the surface shock, which are not well covered by the similarity rule. It is also shown that the high lift coefficient is not exactly proportional to the angle of attack even at the origin near a Mach Number of one.

RAYLEIGH'S PROBLEM IN MAGNETOHYDRODYNAMICS. C. C. Chang and J. T. Yen. Phys. Fluids, July-Aug., 1959, pp. 393-403. 20 refs. USAF-supported extension of Rayleigh's problem to magnetohydrodynamics for the case of a perfectly conducting plate with a transversely applied magnetic field. Induced electric and magnetic fields are both included in the analysis. Results obtained show that along the plate an electromagnetic body force will act in the direction of fluid motion. The results are found to be the same whether the applied magnetic field is fixed in space or attached to the moving plate. A comparison of these results with those of Rossow (magnetic field fixed with fluid) shows opposite trends in the velocity profile. Such discrepancies are discussed.

LAMINAR STEADY-STATE MAGNETOHYDRODYNAMIC FLOW IN AN ANNULAR CHANNEL. Samuel Globe. Phys. Fluids, July-Aug., 1959, pp. 404-407. Analysis considering the steady flow of an electrically conducting, incompressible fluid in the annular space between two infinitely long circular cylinders under a radially impressed magnetic field. The general magnetohydrodynamic equations are simplified by the conditions of the problem to three equations in pressure, velocity, and magnetic field. One equation gives the pressure variation in the radial direction; the other two are coupled equations for the velocity and magnetic field, which are functions of the radial variable only and may be solved in closed form. In the limiting case where the radii of the annulus become infinite, but their difference remains finite, the solution converges on the expression for magnetohydrodynamic flow between infinite planes under a transverse magnetic field.

TOCHNYE RESHENIIA URAVNENII DVIZHENII MAGNITNOI GIDRODINAMIKI, PREDEL'NYKH K AVTOMODEL'NYM. N. N. Kochina. AN SSSR Dokl., May 21, 1959, pp. 528-531. In Russian. Derivation of exact solutions for the equations of magnetohydrodynamics, considering the case of one-dimensional nonsteady motion of an ideal conducting gas. The approach developed previously for the case without magnetic forces is generalized, and the results are presented for the problem of cylindrical symmetry.

A SHALLOW-LIQUID THEORY IN MAGNETOHYDRODYNAMICS. L. E. Fraenkel. GALCIT Rep. (AFOSR TN 59-563) [AD 216758], June, 1959. 74 pp. 18 refs. Extension of the "shallow water" theory to the case of an electrically conducting liquid on a horizontal bottom in the presence of a vertical magnetic field. The approximate equations are based on a small depth/wavelength ratio, the properties of mercury, and a moderate magnetic field strength. Some explicit solutions of the linear equations are obtained for plane flows and for axisymmetric flows in which the velocity vector lies in a vertical, meridian plane.

O PRIBLIZHENNOM METODE ISSLEDOVANIIA PLOSKIKH VIKHREVYKH TECHENII V MAGNITNOI GIDRODINAMIKE. I. I. Nochevkina. AN SSSR Dokl., June 21, 1959, pp. 1,220-1,223. In Russian. Development of an approximate method for studying steady two-dimensional vortex flows of an ideal compressible fluid in a magnetic field, perpendicular to the plane (x, y) of the flow. The interaction problem for the magnetic and hydrodynamic phenomena in the medium of infinite conductivity, as well as the determination of basic parameters of the medium, can be reduced to the solution of a system of partial nonlinear differential equations. The method is used to derive a solution for $M = 1.73$, and a satisfactory approximation is obtained for the range $1.56 \leqslant M \leqslant 1.9$. The method is applicable to the investigation of subsonic and supersonic nonisentropic flows in the limited Mach Number range with a specified form of the equation of state.

O IAVLENII MAGNITNOGO "OTZHATIIA" POTOKA PROVODIASHCHEI SREDY. V. N. Zhigulev. AN SSSR Dokl., May 21, 1959, pp. 521-523. In Russian. Study of the flow of conducting gas around bodies with a magnetic field. A method of solution is developed for the case involving the pinch effect for high magnetic Reynolds Numbers. The problem

of hypersonic flow about a system of parallel linear currents is treated as an illustrative example.

K RASCHETU UDARNYKH VOLN V MAGNITNOI GIDRODINAMIKE. M. I. Kiselev. AN SSSR Dokl., May 21, 1959, pp. 524-527. In Russian. Presentation of a simplified method for the calculation of shock waves in magnetohydrodynamics. It is shown that the boundary conditions along the front of the perpendicular shock wave lead to cubic equations for computing the parameters of the medium behind the front, but can be reduced to quadratic equations due to the presence of all values belonging to index 1 (index 1 covers all parameters of the medium ahead of the front, index 2 covers the region behind the front) and the availability of a cubic root. The method of calculation is described in detail and the results are analyzed, emphasizing the feasibility of the simplified approach, particularly when additional members characterizing the emission and effect of cosmic rays are introduced.

UDARNAIA VOLNA SO SKACHKOM PROVODIMOSTI GAZA V ELEKTROMAGNITNOM POLE. G. A. Liubimov. AN SSSR Dokl., May 11, 1959, pp. 291-294. In Russian. Study of stationary shock waves with a discontinuity in the gas conductivity along its front. Ahead of the shock wave the assumption is made of given parameters of the incident flow, as well as of the intensity of the electric and magnetic fields which, for simplification purposes are assumed to run parallel to the plane of the shock wave. The conductivity behind the shock wave is assumed to be infinite. On this basis, the laws of mass, momentum, and energy conservation, as well as the tangential component of the electrical field are defined. The problem of steady supersonic flow of gas around two-dimensional profiles in an external electromagnetic field is used for illustration purposes.

PECULIARITY OF SHOCK IMPINGEMENT ON AREA CONVERGENCE. A. K. Oppenheim, P. A. Urtiew, and R. A. Stern. Phys. Fluids, July-Aug., 1959, pp. 427-431. 13 refs. AFOSR-supported evaluation of transmitted and reflected waves which are obtained as a result of shocks impinging on area convergences in tubes. A regime discovered during the analysis is specified in terms of functional relationships between shock Mach Numbers and area ratios. For this, there exist two or three solutions at the same time, all satisfying the dynamic boundary conditions imposed by the conservation laws. The ambiguity is resolved by involving the extremum principle of irreversible thermodynamics.

THE PARAMETERS OF A GAS BEYOND A SHOCK WAVE. Yu. P. Lun'kin. Sov. Phys. - Tech. Phys., Feb., 1959, pp. 155-161. 10 refs. Translation. Analysis considering nonequilibrium processes in which some of the degrees of freedom are regarded as completely excited to a corresponding temperature and all others are "frozen" (still at the temperature of the incident flow). It is shown that when the effects of the variable specific heat are taken into account, the parameters of a gas beyond a shock wave are determined by the effective γ and not by $\gamma = c_p/c_v$. Inclusion of the effect of variable specific heat leads to a nonmonotonic dependence of the density on the Mach Number of the incident flow. For gases with low dissociation energies, there can be intersections of the corresponding frozen and equilibrium shock adiabatics and shock polars.

PRIBLIZHENNYI METOD RASCHETA UDARNYKH VOLN I IKH VZAIMODEISTVII. G. M. Liakhov and N. I. Poliakova. AN SSSR Otd. Tekh. Nauk Izv. Mekh. i Mashinostr., Mar.-Apr., 1959, pp. 13-18. In Russian. Development of an approximate method for calculating the shock waves and their interaction. The approximations on which the method is based are stated, and the results are presented for the propagation and reflection of shock waves.

TWO-DIMENSIONAL TRANSONIC UNSTEADY FLOW WITH SHOCK-WAVES. Wiktor Eckhaus. MIT FDRG Rep. 59-3 (AFOSR TN 59-491) [AD 215844], May, 1959. 79 pp. 17 refs. Study of unsteady flow around an airfoil in which the local supersonic regions terminated by shock waves are present in the vicinity of the airfoil. For the unsteady part of the flow, small-perturbations technique is employed and the interaction with the shock wave is taken into account. The case of an oscillating aileron is considered first, and a solution is derived for the pressure distribution on the aileron. It is found that the solution has a simple form when the shock wave is well ahead of the hinge axis of the aileron. As the shock approaches the hinge axis, a correction must be added to the solution. The results are compared with results of a theory which neglects the presence of the shock, and it is found that both agree for a Mach Number of one. The theory is extended to include the case in which the whole airfoil oscillates, but only the solution for the subsonic region behind the shock is treated.

A MATHEMATICAL EXAMPLE DISPLAYING FEATURES OF TURBULENCE. Terence Butler. USAF WADC TR 59-52 [AD 213590], Mar., 1959. 68 pp. 16 refs. Evaluation of Hopf's equations for turbulent flow which retain certain essential features of the Navier-Stokes equations but are much simpler. In the present theory, the properties of turbulent flow as obtained in measurements are expressed by certain statistical averages. The corresponding quantities of Hopf's model are investigated by means of probability theory and a basis for a more detailed comparison is established. It is found that the broader characteristics of turbulence are present in the solutions, but that the inherent simplicity of Hopf's model limits the extent of similarity.

A CONTRIBUTION TO THE ENERGY DECAY LAW OF ISOTROPIC TURBULENCE IN THE INITIAL PERIOD. Hiroshi Tsuji. Tokyo U. Aero. Res. Inst. Rep. 345, May, 1959. 22 pp. 15 refs. Discussion of some self-contradictions involved in

the theories of the linear decay law and of Lin's decay law. A new formulation is presented to determine the decay curve by solving the energy decay equation which, in turn, has been derived from both the energy equation and the vorticity equation. Comparison is made between the three theories using three statistical parameters common to all, and thus the effect of the initial conditions upon the energy decay of turbulence can be examined quantitatively.

TURBULENTNYI SLED I STRUIA V SPUTNOM POTOKE PRI NALICHII PRODOL'NOGO GRADIENTA DAVLENIIA. A. S. Ginevskii. AN SSSR Otd. Tekh. Nauk Izv. Mekh. i Mashinostr., Mar.-Apr., 1959, pp. 31-36. In Russian. Development of an approximate method of calculation for problems of free turbulence in the presence of a longitudinal pressure gradient. The method is based on the use of a polygon to represent the tangential pressure profile in the stream or the wake. The coefficients of the polygon are determined on the basis of boundary conditions along the flow axis and sides by means of differential equations of motion. The expression for the profile together with one of the turbulent friction formulas leads to a closed problem and allows the determination of velocity profiles in the flow or the medium. The analogy between the developed method and those used for calculating the turbulent boundary layer along a hard curvilinear boundary is pointed out.

Internal Flow

METHOD FOR PREDICTING OFF-DESIGN PERFORMANCE OF AXIAL-FLOW COMPRESSOR BLADE ROWS. G. K. Serovy and E. W. Anderson. US, NASA TN D-110, Aug., 1959. 37 pp. 27 refs. Study to determine the accuracy with which axial-flow compressor-blade-row performance at off-design operating conditions may be predicted by a blade-element procedure. The simplified flow model assumed and the equation forms used are similar to those ordinarily used as a basis for solution of the compressor inverse or design problems. Blade-element turning angles and loss coefficients are estimated from correlations of available two- and three-dimensional cascade data for NACA 65-(A_{10})- series compressor blade sections. The complete calculation procedure is outlined and its application to rotating and stationary blade rows is discussed. Performance is predicted for a rotor blade row designed for axial inlet velocity and for a rotor preceded by inlet guide vanes. In each case predicted performance is compared with previously determined experimental results; the method appears to be valid for the configuration types investigated.

RESEARCH ON ROTATING STALL IN AXIAL FLOW COMPRESSORS. I - ON LIFT HYSTERESIS AT MAXIMUM LIFT INCLUDING EFFECT OF CAMBER, R. A. Hartunian. II - ON THE SEPARATION OF THE UNSTEADY LAMINAR BOUNDARY LAYER, R. A. Hartunian and F. K. Moore. III - EXPERIMENTS ON LAMINAR SEPARATION FROM A MOVING WALL, R. J. Vidal. IV - A PRELIMINARY STUDY OF THREE-DIMENSIONAL ROTATING STALL, F. K. Moore. USAF WADC TR 59-75, Pts. I, II, III, IV [AD 216301; AD 216302; AD 216303; AD 216304], Jan., 1959. 25; 25; 26; 20 pp. 43 refs. I - Comparison of the lift hysteresis for an 8 1/2% cambered 6:1 elliptic cylinder with an uncambered one. It is found that the effect of camber is to reduce the magnitude of the hysteresis by 40%. II - Analysis of the singularity near separation for the unsteady and moving-wall cases. It is concluded that, in the former case, the separation criterion of vanishing wall shear applies, and in the latter case separation occurs whenever shear and velocity simultaneously vanish. The Falkner-Skan analysis is also extended to the two fundamental problems. III - Experimental verification of the previous analysis. IV - Analysis of the conditions necessary for the existence of three-dimensional or partial-span patterns of rotating stall of the axial flow compressor within the framework of small perturbation theory. For the infinite two-dimensional cascade, it is shown that a spanwise variation is impossible. It is also shown by a similar method that no disturbance of lift can propagate relative to the blade elements of an axially symmetric compressor which, in terms of mean flow, produces a free vortex-swirl distribution.

PROPULSION AERODYNAMICS; PREDICTION AND CONTROL OF VISCOUS EFFECTS. I - AN INTRODUCTION TO THE BOUNDARY LAYER. II - APPLICATION TO THE DESIGN OF INDUCTION SYSTEMS. J. P. Moran. Grumman Aircraft Eng. Corp. Propulsion Dept., vol. II, Rep. XP-12.11a; XP-12.11b, Apr. 30, 1959. 248; 147 pp. 87 refs. Study of turbulent boundary-layer growth under the influence of pressure gradients considering only steady, two-dimensional flows and neglecting the problem of heat transfer. The laminar boundary layer is considered in enough detail to calculate its development to transition and to locate transition. The developed theory is then applied to the effects of boundary layer on air induction system performance. Problems are studied for shock-free flow without mass transfer, subsonic diffusers, and boundary layer control. Finally, the design of a diffuser to handle the flow through a supersonic side inlet is described.

THE THRUST OF A SUPERSONIC CONICAL NOZZLE WITH NON-ISENTROPIC FLOW. P. N. Rowe. IME Proc., No. 30, 1958, pp. 877-881; Communications, pp. 882-887; Author's Reply, pp. 887, 888. 10 refs. Derivation of an expression for the thrust of a nonideal supersonic conical nozzle in terms of coefficients that can be measured experimentally. The coefficients chosen are discharge coefficient, pressure coefficient, and the geometric divergence coefficient. Expressions are developed for the gas velocity, the area ratio, and the thrust in terms of the pressure ratio, the specific heat ratio, and the above coefficients. Optimum operating conditions are deduced, and it is shown that the jet exit pressure should be greater than atmospheric for maximum thrust.

EFFECT OF BODY INCIDENCE ON TWO AFTERBODIES WITH A REARWARD FACING JET. A.

H. Craven. Coll. of Aeronautics, Cranfield, Note No. 92, Dec., 1958. 61 pp. Investigation showing that a jet issuing from an afterbody significantly increases the magnitude of the normal force, axial force, and pitching moment arising from the external forces but not including the direct reaction of the jet. On the bluff cylindrical afterbody the effect of the jet is comparable in magnitude to the effect of incidence. However, the effect of the jet on the conical afterbody is secondary to the effect of incidence.

STUDY OF THE FLOW INSIDE MACH 4 NUMBER NOZZLE IN THE VERY LOW DENSITY WIND TUNNEL. F. M. Devienne, G. M. Forestier, and J. Souquet. Lab. Méditerranéen de Rech. Thermodynamiques TN (AFOSR TN 59-482) [AD 215735], Mar., 1959. 15 pp. Study of the variations in the static and impact pressures inside the nozzle of a highly rarefied wind tunnel. The measurements indicate that the pressure varies in a continuous manner inside the nozzle and that the different flow regimes (slip-flow, transition, and free-molecular) establish themselves gradually.

TORMOZHENIE SVERKHZVUKOVOGO POTOKA V DIFFUZORNYKH KANALAKH AERODINAMICHESKIKH TRUB. N. N. Shirokov. AN SSSR Otd. Tekh. Nauk Izv. Mekh. i Mashinostr., Mar.-Apr., 1959, pp. 19-24. In Russian. Presentation of results of experiments on the drag process in supersonic flow at the convergent section of diffusing channels. Criteria, defining the maximum possible drag in the flow before the throat, are presented. The effect of Reynolds Number on the diffusor characteristics is determined, and, on the basis of experimental data, an approximate method of solution is developed for calculating the performance of diffusing channels for a given geometry. The method is verified experimentally for various Mach Numbers.

Performance

OPTIMUM PATH OF AN AIRPLANE - MINIMUM TIME TO CLIMB. Theodore Theodorsen. J. Aero/Space Sci., Oct., 1959, pp. 637-642. Application of the theory of variation to the determination of the minimum time to climb for an aircraft of constant weight. It is evident that, when sufficient boundary conditions are given - the beginning and the end point of the path - there is only one curve corresponding to the minimum time to climb. Because of the relative complexity of the resulting differential equation, it is convenient to generate such paths by a step-by-step procedure. The end point is then bracketed by proper choice of the higher derivations at the origin. It is evident that any decrease in weight during the time of the flight may also be properly bracketed by solving for the two limiting cases of initial and final weights of the aircraft. The decrease in weight, however, is actually too small to have any significance on the shape of the path.

Stability & Control

AN ANALYTICAL STUDY OF THE DYNAMICS OF SPINNING AIRCRAFT. I - FLIGHT TEST DATA ANALYSES AND SPIN CALCULATIONS. II - WIND TUNNEL TESTS. J. H. Wykes, G. R. Casteel, and R. A. Collins. USAF WADC TR 58-381, Pts. I, II [AD 203788; 203789], Dec., 1958. 206; 58 pp. 28 refs. Analysis of flight test data to show the relative importance of weight, inertia, engine, and aerodynamic influences acting during a spin of a typical fighter aircraft (F-100D). Both static and rotary derivative data are used in a number of six degrees of freedom spin calculations, which are compared against flight data. These comparisons show that it is possible to calculate the response characteristics of an aircraft through all phases of the spin from the incipient phase through recovery. Finally, the results of a series of low-speed wind-tunnel force tests of the F-100D from 0^{o} to 90^{o} angle of attack and sideslip angles of 0^{o} to 20^{o} are presented. In addition, the effects of Reynolds Number and the effect of tripping the fuselage boundary layer to simulate high Reynolds Number flow are investigated. A simple, but effective way of correcting data for tunnel blockage effects when a model is at high angles of attack is also presented.

THE DETERMINATION OF AIRCRAFT STABILITY COEFFICIENTS FROM FLIGHT TEST DATA. I - THEORETICAL CONSIDERATIONS, L. E. Wilkie, M. N. Springer, and L. L. Mazzola. II - LONGITUDINAL INVESTIGATIONS, L. E. Wilkie and M. N. Springer. III - LATERAL INVESTIGATIONS, L. L. Mazzola and M. E. Hoult. USAF WADC TN 57-410, Pts. I, II, III [AD 213869; AD 213870; AD 213871], Apr.; July, 1958. 142; 131; 66 pp. 55 refs. I - Discussion of three general problems associated with the extraction of stability coefficients. These are the determination of an adequate mathematical model of the dynamic system, the selection of the appropriate technique for the extraction of the coefficients, and a knowledge of the exact number of unknown coefficients which can be theoretically determined from any given response. II - Extraction of the longitudinal stability coefficients in the Z-force and pitching-moment equations from digitally-simulated aircraft responses by the integral method of Shinbrot, the derivative method, and a new statistical method. III - Extraction of the lateral stability coefficients in the yawing and rolling moment equations using the three methods as stated above.

Wings & Airfoils

FLÜGELPROFILE. Hansheiri Thomann. Aero Rev., May; June; July; Aug., 1959, pp. 314-317; 387, 388; 452, 453; 513, 514. In German. Detailed survey of wing profiles including such related problems as the effect of curvature and thickness, pressure distribution, boundary layer, transition region, and Reynolds Number. Experimental techniques used in the investigation of these phenomena are covered, and such aspects as angle of attack, lift and drag, and gust loads are analyzed.

ANALYSIS OF COMPUTED FLOW PARAMETERS FOR A SET OF SUDDEN STALLS IN LOW-SPEED TWO-DIMENSIONAL FLOW. Appendix - REVIEW OF EXPERIMENTAL EVIDENCE FOR THE TWO HYPOTHETICAL MECHANISMS OF

NOSE STALL. W. T. Evans and K. W. Mort. US, NASA TN D-85, Aug., 1959. 24 pp. 30 refs. Study of nose stall in airfoils from which it is inferred that there are two distinct mechanisms of stall, presumed to be "bubble-bursting" and "re-separation." For a set of airfoils attributed to the latter mechanism on the basis of a criterion proposed by Tani and Owen independently, a correlation is demonstrated between high theoretical velocity peaks at stall and either steep initial adverse gradients or thin boundary layers in the region of these gradients. The correlation does not apply to stalls specifically attributed to bubble-bursting.

TRANSONIC AERODYNAMIC CHARACTERISTICS OF SEVERAL BODIES HAVING ELLIPTICAL CROSS SECTIONS AND VARIOUS PLAN FORMS. R. A. Taylor. US, NASA TN D-14, Aug., 1959. 31 pp. Presentation of lift, drag, and pitching-moment characteristics for progressively shortened bodies having major to minor axis ratios of 3 and 4 and lengths of 58%, 72%, and 85% of the closure length. The bodies were tested through an angle-of-attack range from -2° to $+12^{\circ}$ and a Mach Number range from 0.40 to 1.20, with Reynolds Numbers varying from approximately 9×10^6 to 21×10^6.

AEROELASTICITY

NELINEINYE ZADACHI USTOICHIVOSTI PLOSKIKH PANELEI PRI BOL'SHIKH SVERKHZVUKOVYKH SKOROSTIAKH. V. V. Bolotin, Iu. V. Gavrilov, B. P. Makarov, and Iu. Iu. Shveiko. AN SSSR Otd. Tekh. Nauk Izv. Mekh. i Mashinostr., May-June, 1959, pp. 59-64. In Russian. Investigation of the stability of elastic rectangular plates in supersonic flow at zero angle of attack. The aerodynamic forces are determined by using an asymptotic formula derived previously for $M \gg 1$. The approximate solutions for cylindrical deformations are verified on an electronic computer, including the cases of flow (a) on one side and (b) on both sides of the plate. Analytical procedures used in the calculation are described, and the results are compared with data obtained on the basis of different parameters.

AN EXAMINATION OF METHODS OF BUFFETING ANALYSIS BASED ON EXPERIMENTS WITH WINGS OF VARYING STIFFNESS. A. G. Rainey and T. A. Byrdsong. Appendix A - DERIVATION OF EQUATIONS GOVERNING BUFFET RESPONSE OF A WING. D. D. Davis, Jr. US, NASA TN D-3, Aug., 1959. 28 pp. 12 refs. Study of the validity of some of the assumptions used in the analysis of buffeting loads by means of wind-tunnel tests of models differing in stiffness. A linear analysis predicts buffeting loads which are high by a factor of about 25%. This difference may be associated with a relieving effect which causes flexible wings to generate smaller buffeting forces than a more rigid wing. A prediction based on aerodynamic damping only, which apparently contains compensating inaccuracies, provides values of buffeting loads which are closer to the measured values than those predicted by the more complete analysis including both structural and aerodynamic damping.

A MATRIX APPROACH TO FLUTTER ANALYSIS. W. P. Rodden. IAS, SMF Fund Paper No. FF-23, 1959. 38 pp. 20 refs. Members, $0.75; nonmembers, $1.50. Presentation of a matrix method that is equally applicable to low as well as high aspect ratio surfaces, so that three-dimensional aerodynamic theories can be utilized as they become available. A survey on the state-of-the-art of aerodynamic influence coefficients is made, and the interpolation problem of unifying the structural and aerodynamic collocation points is discussed. The sweeping for higher modes and the convergence problems of the complex matrix iteration associated with close roots are considered, and the modifications to the matrix equation for the analysis of free-free symmetric and antisymmetric flutter are presented. A means of combining the computational simplicity of the assumed mode method and the generality of the matrix method is shown. Finally, an example of a cantilever wing flutter analysis is outlined.

INVESTIGATION OF METHODS FOR COMPUTING FLUTTER CHARACTERISTICS OF SUPERSONIC DELTA WINGS AND COMPARISON WITH EXPERIMENTAL DATA. Appendix A - STRIP THEORY APPROXIMATION TO AERODYNAMIC FORCES. Appendix B - BOX THEORY APPROXIMATION TO AERODYNAMIC FORCES. C. H. Wilts. US, NASA TN D-5, Aug., 1959. 65 pp. 13 refs. Study of the flutter characteristics of two delta wings using an analog computer. Using strip theory and the box method to represent the aerodynamics, the analog flutter characteristics were also compared with experimental values. A partial check of the analog procedures is furnished by a flutter analysis on a digital computer.

VIBRATION OF UNIFORM SQUARE PLATES BOUNDED BY FLEXIBLE BEAMS. H. L. Cox and W. A. Benfield. ASA J., July, 1959, pp. 963-966. Development of an approximate solution for vibrating, uniform, elastic plates using finite difference expressions for structures with various ratios of edge beam to plate stiffness and edge beam to plate mass. The fundamental frequencies are determined by means of Poisson's ratio.

FUELS & LUBRICANTS

BORO E DERIVATI COME COMBUSTIBILI AD ALTA ENERGIA. R. M. Corelli. Missili, June, 1959, pp. 5-16. 15 refs. In Italian. Analysis covering the properties of boron and its derivatives for use as high energy fuels. Solid, liquid, and gaseous types are included in the study, and the metallurgical aspects, as well as the physical and chemical properties of boron are evaluated. Methods of preparation are also presented along with a discussion of the applicability of these fuels to rocket propulsion systems.

INSTRUMENTS

UNTERSUCHUNGEN DES TEMPERATURGANGES INNERHALB VON BORDGERÄTEN UND

IHREN BAUTEILEN. O. Weber. DFL Inst. Luftfahrzeugf., Bericht No. 107, Feb., 1959. 53 pp. In German. Investigation of the effects of temperature variations in an infinitely long homogeneous cylinder used as a simple model for airborne instruments. Based on the results thus obtained, a barometric altimeter, a turn indicator, a thermos flask (representing an equilibrium container for a variometer), and a panel clock are tested under conditions of rapidly varying ambient temperatures and rotation and cooling of the components. The basic problems studied are: (a) length of time required for all components to adopt the same temperature after changing of the test temperature, and (b) simulation of operating conditions where all components of an aircraft instrument show the same temperature during the actual measuring process.

MATHEMATICS

Physical Applications

ON SERIES EXPANSIONS IN MAGNETIC REYNOLDS NUMBER. V. J. Rossow. US, NASA TN D-10, Aug., 1959. 44 pp. 40 refs. Derivation of solutions of magnetohydrodynamic flow problems by expanding various flow parameters in a negative or positive power series of the magnetic Reynolds Number. Higher order approximations for a laminar stream are found by iteration of the solution obtained on the basis of the assumption that the magnetic Reynolds Number is small or zero.

LIEU DES RACINES D'UNE EQUATION ALGEBRIQUE DEPENDANT D'UN PARAMETRE; APPLICATION A LA STABILITE ET AU GUIDAGE DES FUSEES. Francisque Salles. France, Min. de l'Air PST 351, 1959. 68 pp. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 1,810. In French. Theoretical investigation of the locus of complex roots of an algebraic equation and application of a practical method for determining that locus to transfer functions of servomechanisms and to hydrodynamic flows. The importance of the mathematical approach to stabilizing and guiding rockets having an almost vertical flight path is stressed, and an example for the numerical integration of a differential equation system with variable coefficients, applicable to the calculation of rocket trajectories, is given.

MISSILES, ROCKETS, SPACE CRAFT

1958 NASA/USAF SPACE PROBES (ABLE -1). I - SUMMARY. US, NASA Memo. 5-25-59W, vol. I, Final Rep., June, 1959. 84 pp. Survey of the launchings of three Able-1 vehicles and presentation of details of the program, vehicles, payloads, firings, tracking, and results.

IN-FLIGHT IMPACT AND APOGEE COMPUTATIONS FOR VANGUARD. H. H. Germond. RCA Data Proc. TR 49 (AFMTC TR 59-9) [AD 216293], May 25, 1959. 89 pp. 15 refs. Description of a method by which the range, azimuth, and elevation of a Vanguard vehicle are determined every 0.1 sec. by one or the other of two radars. During the powered first and second stages of flight a prediction is made as to where the vehicle would impact if the thrust were to be terminated. This information is displayed continuously on a plotting board. After burnout or cutoff of the second stage, computations are made (every tenth of the sec.) of the time remaining before the vehicle should reach apogee. This and other information pertinent to the initiation of the third stage is displayed on a console.

ZWEI SPEZIELLE MONDEINFANG-BAHNEN IN DER RAUMFAHRT UM ERDE UND MOND. B. Thüring. Astronautica Acta, Fasc. 3-4, 1959, pp. 241-250. In German. Calculation of two special trajectories of the three-body problem for the Earth-Moon plane as representative of "bottle neck" and "capture trajectories." The Lagrangian libration points L_1 and L_2 are passed through a narrow pass of the limit curves - once from the geolunar interior space, the other time from the geolunar exterior space. Both of them lead to a "capture" by the Moon. The trajectories are characterized by a frequent driving round the Earth or the entire Earth-Moon system, before passing through the narrow pass at L_1 or L_2, respectively.

UNE ETUDE DU TRANSFERT DE LA CHALEUR D'UN ENGIN LORS DE SA RENTREE DANS L'ATMOSPHERE TERRESTRE. Daniel Wein. Rev. Fr. Astron., Jan., 1959, pp. 43, 45-50. In French. Study of the thermodynamic equilibrium of the nose of a vehicle re-entering the earth's atmosphere at a velocity of 10,000 ft./sec. The nose is covered with a plastic, partially ablated coating which provides an increased protection for the internal sections from severe aerodynamic heating. The results were obtained by solving a system of partial differential equations using an electronic computer. It is shown that ablation starts about 15 sec. after re-entry and lasts less than 20 sec., with less than 0.1 in. of the surface having been ablated. The temperature curves show a sharp decrease in slope at the beginning of ablation, thus emphasizing the advantage of the method.

COLD RE-ENTRY OF SPACE VEHICLES AT METEOR SPEEDS. D. H. Robey. Astronautica Acta, Fasc. 3-4, 1959, pp. 224-240. 12 refs. Study of the possibility of using frozen water as a protective covering for space vehicles re-entering at parabolic velocity. A series of curves for solid ice spheres, showing the thermal and dynamic re-entry curves, is presented. The results are very encouraging, especially for the cold return of instrumentation where steep re-entries and high decelerations can be tolerated. More gentle re-entries require thicker ice layers, but the high temperature problem can be avoided.

DECAY OF SPIN IN SPUTNIK I. J. W. Warwick. Planetary & Space Sci., Jan., 1959, pp. 43-49. Study of the secular change taking place in the spin-fading rate on the basis of observations of the radio transmissions from Sputnik I over a period of three weeks. This effect allows a determination

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of atmospheric density near the perigee point. Some fluctuations in the spin decay appear to be real and may result from small changes in the orientation of the spin axis within the satellite. An alternative interpretation in terms of charged drag, resulting from motion of the satellite through the ionospheric plasma, requires a charge of at least 10^4 volts on the satellite. Such a charge might be acquired in the auroral zone.

GRAPHICAL REPRESENTATION OF RE-ENTRY TRANSFER ORBITS. L. E. Wolaver. USAF WADC TN 59-141 [AD 214761], Mar., 1959. 66 pp. Analysis of two-dimensional transfer orbits between a circular orbit in a vacuum above a spherical Earth and a point on that rotating Earth. These re-entry orbits are characterized by two parameters, e, the eccentricity and, p, the semilatus rectum. Constant loci lines in this e-p plane are presented; they are modified Vertregt diagrams. The loci considered consist of re-entry angle, re-entry velocity, retro-thrust required, retro-thrust alignment angle, time-to-impact, range-to-impact, target lead angle at application of retro-thrust, and target-satellite angle at impact. Both direct and apogee routes are considered.

ESCAPE FROM A CIRCULAR ORBIT WITH FINITE VELOCITY AT INFINITY. R. S. Long. Astronautica Acta, Fasc. 3-4, 1959, pp. 159-162. Analysis of the problem of programing the thrust direction of a rocket in order to escape from a circular orbit with minimum expenditure of fuel, considering the assumptions that the rocket thrust per unit mass is large and constant, and that the velocity to be reached at infinity is specified. The use of transverse thrust and of tangential thrust is also considered. It is found that tangential thrust gives a close approximation to the more complex optimal thrust program.

PHYSICS

Astrophysics

NEKOTORYE TOCHNYE RESHENIIA URAVNENII MAGNITNOI GAZODINAMIKI PRI NALICHII SIL SOBSTVENNOGO TIAGOTENIIA I NULEVOGO GRADIENTA TEMPERATURY. E. V. Riazanov. AN SSSR Dokl., June 21, 1959, pp. 1,224-1,226. In Russian. Derivation of certain exact solutions for the equations of magnetogasdynamics describing one-dimensional unsteady motion of an ideal gravitating gas in the presence of cylindrical symmetry for the case in which the absence of the temperature gradient in the flow region is assumed. The other assumptions introduced into the calculation state that the velocity, v, of the gas particle is a linear function of its distance, r, from the axis of symmetry; the conductivity of the gas is infinite; and the viscosity and heat conductivity are absent.

PRIMERY TOCHNYKH RESHENII ZADACH O RASPROSTRANENII VZRYVNYKH VOLN V GRAVITIRUIUSHCHEM GAZE PRI NULEVOM GRADIENTE TEMPERATURY. E. V. Riazanov. AN SSSR Dokl., June 11, 1959, pp. 955-957. In Russian. Derivation of exact solutions for problems of detonation waves propagating in a gravitating gas with zero temperature gradient, encountered in the study of star scintillation. A system of partial differential equations, in which the condition $\partial T/\partial r = 0$ replaces the adiabatic equation, is derived to describe the one-dimensional "homothermal" motions of an ideal gas in its own gravity field with spherical symmetry. The initial density distribution, the mass and pressure distribution, and the mechanical conditions along the wave front are stated.

POWER PLANTS

UTILIZATION OF UPPER-ATMOSPHERE ATOMIC-OXYGEN RECOMBINATION FOR PROPULSION. A. Zukerman and C. B. Kretschmer. Aerojet-Gen. TN 28 (AFOSR TN 59-517) [AD 216292], Apr. 10, 1959. 90 pp. 15 refs. Study of the fuelless ram-jet, a ram-jet with fuel addition, and a catalytic ram rocket as possible upper-atmosphere propulsion systems. It is shown that the fuelless ram-jet cannot provide enough thrust to sustain a satellite in the atomic-oxygen layer. The investigation of the ram-jet with mass addition shows that with fuels similar to NO_2 (in molecular weight and heat release) enough thrust can be derived to overcome the external drag, but not the total drag. Certain configurations of the catalytic ram rocket show promise of sustaining a satellite for a considerable length of time but at a great expense in cooling fluid.

Jet & Turbine

POWERPLANTS FOR VTOL AIRCRAFT: PERFORMANCE CALCULATIONS FOR SEVERAL HYPOTHETICAL TURBOFAN ENGINES. Appendix A - ANALYSIS AND COMPUTATION. Appendix B - TABULATED PERFORMANCE DATA. Appendix C - WEIGHT ESTIMATES FOR TURBOFAN ENGINES. E. P. Cockshutt, N. Galitzine, and T. Weibust. Canada, NRC Aero. Rep. LR-256, July 17, 1959. 80 pp. Tabular presentation of calculated performance data for a wide range of altitudes, forward speeds, and engine speeds obtained on four bypothetical aft-turbofan engines of by-pass ratios of 0, 1.39, 3.13, and 8.24. These performance data are used along with weight estimates to illustrate the application of turbofan engines to a typical VTOL mission. It is shown that, on the basis of power-plant system's weight (engine plus fuel), the highest by-pass cycle is clearly superior. The tendency of the fan to overspeed at high forward velocities affects the high by-pass cycle so that the gas generator must be throttled back considerably. The high level of installed thrust indicates that the thrust reduction accompanying throttling is no problem, except insofar as it adversely affects the specific fuel consumption.

Rocket

FLAME TEMPERATURE OF A LIQUID-FUEL JET ENGINE. I, II. N. N. Sobolev, M. M. Belousov, G. M. Rodin, A. G. Sviridov, N. G. Skorobogatov, F. S. Faizullov, V. F. Kitaeva, and A. I. Fedorov. Sov. Phys. - Tech. Phys., Jan., 1959, pp. 24-37. 14 refs. Translation. Survey of the pyrometric

investigation of the flame of a liquid-fuel rocket engine working on mixtures of "tonka" (a mixture of 50% xylidine and 50% triethylamine) and HNO_3, kerosene and HNO_3, and kerosene and liquid oxygen. It is found that in all three cases the emission spectrum is continuous and that the main source of the radiation are fine soot particles formed during the combustion process. The absorptive power and energy distribution are studied, and systematic measurements of the flame temperature using the color method show that the experimental and calculated temperatures obtained on the assumption of steady-state outflow of combustion products are in good agreement.

THEORETICAL PERFORMANCE OF LIQUID HYDROGEN WITH LIQUID OXYGEN AS A ROCKET PROPELLANT. Sanford Gordon and B. J. McBride. US, NASA Memo. 5-21-59E, June, 1959. 139 pp. 25 refs. Calculation of theoretical performance for both equilibrium and frozen composition during expansion. Data are determined for four chamber pressures and a wide range of pressure and oxidant-fuel ratios. Parameters included are specific impulse, specific impulse in a vacuum, combustion-chamber temperature, nozzle-exit temperature, molecular weight, characteristic velocity, coefficient of thrust, ratio of nozzle-exit area to throat area, specific heat at constant pressure, isentropic exponent, viscosity, thermal conductivity, Mach Number, and equilibrium gas composition.

NIZHNIAIA VETV' KRIVOI GIUGONIO KAK SOVOKUPNOST' TOCHEK, OPISYVAIUSHCHIKH REZHIMY GORENIIA V KAMERAKH REAKTIVNYKH DVIGATELEI. Ia. K. Troshin. ANSSSR Otd. Tekh. Nauk Izv. Energ. i Avtom., Mar.-Apr., 1959, pp. 3-12. 13 refs. In Russian. Study indicating that, when idealized, the lower part of the Hugoniot curve can describe the real combustion regimes in tubes and in rocket combustion chambers. The relationship is established between a certain point on the curve, corresponding to a specific combustion regime, and the convergence ratio of a supersonic Laval nozzle. Relationships are also given which can be used to define, up to the first approximation, the basic engine parameters, as well as the degree of combustion boosting in a cylindrical chamber.

ODNA ZADACHA NESTATSIONARNOI TEPLOPROVODNOSTI. V. S. Zarubin. AN SSSR Otd. Tekh. Nauk Izv. Energ. i Avtom., Mar.-Apr., 1959, pp. 38-44. In Russian. Investigation of the nonsteady heat transfer in a liquid rocket power plant. The following characteristic aspect of the problem is emphasized: the internal and the external walls of the chamber are connected through the phenomenon of convective heat transfer in the cooling liquid with a time-dependent temperature. The heating of the cooling liquid dt_2 over the sector dF of the cooled surface is assumed to be proportional at any moment to the temperature of the liquid over this sector, taken at the same time. Results of experiments covering the ignition, burning, and termination stages are presented.

L'ECOULEMENT A VITESSE VARIABLE DANS LA PROPULSION DES FUSEES. Julius Ulam. Rev. Fr. Astron., Sept., 1958, pp. 23-34. In French. Study of the increase in the characteristic rocket velocity, or of the economy of energy and mass, achieved through the application of the optimum outflow principle. The problem of the maximum characteristic velocity is analyzed in terms of the optimum distribution of the total mass between the dead mass, the energy-bearing mass (fuel), and the passive mass (propellant). This aspect also includes the case of constant velocity.

VERGLEICH DES ENERGIEBEDARFES VON RAKETEN MIT KONSTANTER BZW. VARIABLER STRAHLGESCHWINDIGKEIT. Günter Zebel. Raketentech. & Raumfahrtforsch., July-Sept., 1959, pp. 81, 82. In German. Comparison of the required energy for a rocket operating with constant velocity and a rocket having an exhaust velocity equal to the velocity of the missile to achieve the highest performance. The basic equations are integrated showing that, for space flight missions, the second type of rocket requires considerably less energy and is superior to the constant exhaust velocity rocket.

RESEARCH, RESEARCH FACILITIES

Wind Tunnels

USE OF PERFORATED WALLS FOR SHOCK CANCELLATION AT SUPERSONIC SPEEDS. H. Ramm and M. Jones. USAF AEDC TR 59-15, Aug., 1959. 97 pp. Presentation of the results of tests conducted in a 1-ft. supersonic wind tunnel on two-dimensional and axisymmetric three-dimensional models in order to determine the shock cancellation characteristics of perforated walls at supersonic Mach Numbers up to 3.15. The test section wall configurations included walls with holes drilled normal to the wall surface and holes slanted 60° to obtain differential resistance for inflow and outflow. The influences causing nonlinear wall characteristics are found to be the ratio of the boundary-layer thickness to hole diameter and the pressure recovery in the holes.

TECHNIQUES OF FLOW VISUALIZATION USING WATER AS THE WORKING MEDIUM. D. W. Clutter, A. M. O. Smith, and J. G. Brazier. Douglas Rep. ES 29075, Apr. 15, 1959. 85 pp. 16 refs. Description of the following methods for flow visualization: aluminum powder, either on the surface or suspended in water; electrochemical techniques using tellurium wire, hydrogen bubbles, and starch iodine; dyes, both in liquid and ointment form; luminol, a fluid that becomes luminous when it reacts with another fluid; the air-bubble technique of fairing a blunt body; and the use of gravity waves on the water surface as an analog to shock waves in the supersonic flow of air. For the visualization of three-dimensional flows, it is shown that the hydrogen bubble technique is a practical and inexpensive solution.

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MEASUREMENT OF AERODYNAMIC DAMPING AND STIFFNESS DERIVATIVES IN FREE OSCILLATION WITH AUTOMATICALLY RECYCLED FEEDBACK EXCITATION. K. J. Orlik-Rückemann. Canada, NRC Aero. Rep. LR-246, June, 1959. 11 pp. Description of apparatus for measuring aerodynamic longitudinal stability derivatives on half models. By introducing automatic read-out and recycling in the NAE 30-in. wind tunnel, the technique of free oscillation with feedback oscillation is improved, and the speed of operation and the reliability of data obtained are increased.

RECHERCHES EXPERIMENTALES SUR LES ONDES DE CHOC PRODUITES PAR LES DECHARGES CONDENSEES DANS LES GAS RARES. Michel Cloupeau. France, Min. de l'Air PST 352, 1959. 62 pp. 45 refs. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 1,180. In French. Experimental investigation of shock waves produced by the condensed discharges in rare gases. It is shown that the shock waves return to the plasma after having been reflected on the tube walls and generate important changes in the intensity and spectral composition of the radiation. Tests with xenon, krypton, and argon tubes were made, and results on longitudinal and transversal waves are presented along with an analysis of various related phenomena.

ROTATING WING AIRCRAFT, HELICOPTERS

TEORIIA IDEAL'NOGO NESUSHCHEGO VINTA VERTOLETA. A. S. Braverman. AN SSSR Otd. Tekh. Nauk Izv. Mekh. i Mashinostr., Mar.-Apr., 1959, pp. 25-30. In Russian. Application of the Glauert hypothesis to develop the theory of an ideal lifting helicopter rotor, taking into account the assumption of a constant induced velocity over the entire blade-swept disc. The applicability of the derived formulas to the case of a real rotor is illustrated, and the process used to determine the aerodynamic characteristics of the lifting rotor in the system of flow coordinates is shown for unknown values of the angle of attack and the characteristics of the rotor in the related system of coordinates. Other simplified assumptions introduced into the calculation are also stated.

STRUCTURES

Beams & Columns

THIN-WALLED COMPRESSION MEMBERS. A. Pflüger. Hannover Tech. Hochschule Inst. Statik Rep. 1 (AFOSR TN 59-291) [AD 212923], Dec., 1958. 37 pp. Investigation of the buckling stress of centrally loaded columns consisting of thin-walled elements subject to normal column buckling, torsional-flexural buckling, and local buckling of the walls. Theoretical calculations of the relations within the range of elasticity and up to the buckling strength are made and evaluated to solve the problem of the practical dimensioning of such columns.

Cylinders & Shells

AN IMPROVED FIRST-APPROXIMATION THEORY FOR THIN SHELLS. Appendix A - SMALL RIGID-BODY MOTIONS. Appendix B - EQUATIONS OF THE THEORY FOR A CIRCULAR CYLINDER. J. L. Sanders, Jr. US, NASA Rep. 24, June, 1959. 23 pp. Derivation of a theory in which all strains vanish for any rigid-body motion in contrast to the results of Love's theory. Expressions for the stress resultants and couples which satisfy the homogeneous equilibrium equations are given in terms of three stress functions.

DIE LÄNGSGEDRÜCKTE ORTHOTROPE KREISZYLINDERSCHALE BEI INNENDRUCK. Walter Schnell and Christian Brühl. ZFW, July, 1959, pp. 201-207. In German. Calculation of the critical axial load for orthotropic shells under internal pressure by means of the classical, linear theory of stability, and comparison with experimental results for plywood cylinders. The dependence of critical buckling values on rigidity parameters and internal pressure is shown to have the same trend both in theory and experiments. The theoretical absolute values, however, are higher by about 20% to 30%.

THE ANALYSIS OF FUSELAGES OF ARBITRARY CROSS-SECTION AND TAPER. V. J. H. Argyris and S. Kelsey. Aircraft Eng., July, 1959, Establishment of internal stress resultants for the open rings in the fuselage due to the various statically equivalent and self-equilibrating load systems. The determination of the frame redundancies leads immediately to the corresponding results for closed rings. The procedure is developed for both single and double-cell cross-sections with either singly- or doubly-connected rings. A brief account is also given of the flexibility of a diaphragm or bulkhead, describing how either the force or displacement method may be used. Finally, the effects of thermal stresses on frames are considered.

SPHERICAL CAP SNAPPING. H. B. Keller and E. L. Reiss. J. Aero/Space Sci., Oct., 1959, pp. 643-652. 13 refs. AFOSR-supported study of a nonlinear boundary value problem for the determination of the rotationally symmetric deformations of a clamped spherical cap under external pressure, using finite difference equations. Buckled and unbuckled equilibrium states are obtained and the shape of the pressure-deflection curve, which is usually assumed for these states, is verified for a large class of caps. Estimates are given for the upper and lower buckling loads and the intermediate buckling load. It is found that boundary layers develop in the buckled states both as the loading increases and the thickness of the shell decreases.

Elasticity & Plasticity

RAZRESHIMOST' PLOSKOI ZADACHI TEORII MALYKH UPRUGO-PLASTICHESKIKH DEFORMATSII. Iu. P. Krasovskii. AN SSSR Dokl., June 11, 1959, pp. 961-963. In Russian. Analysis of the feasibility of solving two-dimensional problems in the theory of small elastoplastic deformations. The calculation is made on the basis of an inequality used in the solution of nonstationary hydrodynamic

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problems and without introducing any of the previously used limitations. Several boundary problems are analyzed, and the results are presented.

PROSTRANSTVENNAIA ZADACHA DIFFRAKTSII UPRUGOI VOLNY NA OSTROM REBRE. A. F. Filippov. Prikl. Mat. i Mekh., July-Aug., 1959, pp. 691-696. In Russian. Derivation of an exact solution for the problem of diffraction of nonsteady, plane elastic waves propagating in a three-dimensional space filled with a homogeneous, isotropic elastic medium, with a slot in the form of a semispace. The method of functional invariant solutions is used in the calculation.

Plates

ON LARGE DEFLECTION OF CURVED STRIPS UNDER COMBINED THERMAL AND PRESSURE LOADINGS. Appendix A - DERIVATION OF GOVERNING EQUATIONS FOR STRIPS FROM REISSNER'S VARIATIONAL PRINCIPLE. M. M. Chen. MIT ASRL TR 76-2 (AFOSR TN 59-676), May, 1959. 52 pp. 17 refs. Derivation based on Reissner's variational principle of the governing equations for large deflections of initially curved strips, including thermal force and thermal moment effects. Exact solutions are obtained for the cases corresponding to net tensile, compressive, and zero in-plane forces with arbitrarily distributed thermal loads and small initial curvature. Numerical examples are given for a clamped-clamped strip with a particular initial shape, temperature distributions, and uniform pressure.

Thermal Stress

CREEP-STRESS ANALYSIS OF THIN-WALLED STRUCTURES. S. A. Patel, K. A. V. Pandalai, and B. Venkatraman. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 497 (AFOSR TN 59-665), July, 1959. 40 pp. 10 refs. Review of stress-analysis methods for structures subject to creep, assuming the structure to be at a uniform temperature and the elastic deformations negligible in comparison with creep deformations. Under these assumptions, the creep problems of thin-walled structures are first reduced to analogous problems of the same structure made of nonlinear elastic materials. The stress analyses are then carried out with particular reference to structures with closed and open cross sections and subjected to pure torsion, bending, and shear.

TRANSIENT THERMAL STRESSES IN THE ELASTIC SLAB. C. H. J. Johnson. Australia, ARL Mech. Eng. Note 232, Mar., 1959. 16 pp. Derivation of a solution to the problem of determining the transient thermal stress distribution in an infinite elastic slab due to the sudden simultaneous application of a temperature T_1 to one face and a temperature T_2 to the other face, the initial conditions being zero and with zero surface tractions. The solution is presented in series form whose successive terms give the stress at a particular depth in a semi-infinite solid with a constant temperature boundary condition. This result is analogous to the solution of problems in transmission line theory in terms of multiply reflected waves. The solution in this form converges rapidly, except for large values of the time.

Wings

A PRELIMINARY ANALYSIS OF THE PENALTIES ASSOCIATED WITH PIERCING A WING TORSION BOX WITH A GRID OF HOLES. A. H. Hall. Canada, NAE LR 236, Jan. 1, 1959. 16 pp. Analysis relating to a conventional aircraft that is modified by the addition of fans housed in the wing plane to provide VTOL operation. The influence of a grid of holes in the wing torsion box on top level speed is inferred by the torsional stiffness criterion for wing divergence. The probable weight penalty incurred in restoring the stiffness to its original, or an intermediate value, is estimated.

THERMODYNAMICS

THE FREEZING AND MELTING TIMES OF SLABS AND CYLINDERS. D. C. Baxter. Canada, NRC Div. Mech. Eng. Rep. MK-1, Feb., 1959. 40 pp. 14 refs. Presentation of general results for the time required to freeze or melt slabs and cylinders of a pure substance initially at the fusion temperature and exposed to a constant ambient temperature, as obtained on a PACE analog computer. Difference-differential equations are derived, and the results are compared with solutions obtained previously by London and Seban. Several charts illustrating the effect of fusion times and temperature and enthalpy changes are also included.

AEROTHERMODYNAMIC AND ELECTRICAL PROPERTIES OF SOME GAS MIXTURES TO MACH 20. W. Chinitz, C. L. Eisen, and R. A. Gross. (ARS 13th Annual Meeting, New York, Nov. 17-21, 1958.) ARS J., Aug., 1959, pp. 573-579. 11 refs. Presentation of pressure, temperature, chemical composition, and electrical conductivity data for gas mixtures behind strong air shocks and for detonations of hydrogen-air and acetylene-air mixtures. A digital computer program has been developed which solves the simultaneous aerodynamic and chemical equilibrium equations. The latest thermodynamic and collision cross-section data are used. Data are also presented, wherein the initial gas composition was varied to obtain the maximum electrical conductivity for a given shock or detonation strength.

THEORY OF RADIATION FROM LUMINOUS SHOCK WAVES IN NITROGEN. P. Hammerling, J. D. Teare, and B. Kivel. Avco Everett Res. Lab. Res. Rep. 49 (AFBMD TR 59-3), June, 1959. 25 pp. 14 refs. (Also in Phys. Fluids, July-Aug., 1959, pp. 422-426.) Calculation of the properties behind a normal shock as a function of time. These include the variation of temperature, composition, ionization, and the intensity of radiation from the N_2^+ first negative band system. This calculation incorporates a rate equation for the dissociation of nitrogen, the conservation laws, an equation describing vibrational relaxation, and a method of coupling the vibrational relaxation with the dissocia-

tion rate. The N_2^+ radiation is computed assuming excitation of the radiating state by collision with vibrationally excited nitrogen molecules.

Combustion

O STRUKTURE TURBULENTNOGO PLAMENI GOMOGENNYKH I GETEROGENNYKH SMESEI. V. Ia. Basevich and S. M. Kogarko. AN SSSR Otd. Tekh. Nauk Izv. Energ. i Avtom., Mar.-Apr., 1959, pp. 13-20. In Russian. Investigation of the structure of turbulent flames in homogeneous and heterogeneous mixtures. The concentration and the temperature of fuel, as well as its burning velocity in a turbulent flame, are determined experimentally for benzene and kerosene. The installation and test methods are described in detail, and the results are analyzed.

ON THE STABILITY OF LAMINAR FLAME-FRONTS. Wiktor Eckhaus. MIT FDRG Rep. 59-4 (AFOSR TN 59-562) [AD 216757], May, 1959. 94 pp. Study of the effect of disturbance on the internal flame structure using small perturbations techniques. A formula for the nonsteady flame propagation velocity is derived on the assumption that flame thickness is small compared to the wavelength of the disturbances. The flame velocity is shown to depend on the curvature of the flame and on the perturbations of fluid velocities on the flame-boundary. The expression for the flame velocity contains coefficients which depend on the physical properties of the mixture that is being burned. Using these results in stability analysis, it follows that the properties of the mixture, as expressed in terms of coefficient of heat conductivity and various coefficients of diffusion, actually determine the stability picture.

FLAME STABILITY EFFECT OF GASES EJECTED INTO A STREAM FROM A BLUFF-BODY FLAMEHOLDER. E. L. Wong. US, NASA TN D-128, Aug., 1959. 26 pp. Study of the effect of gas ejection from a bluff-body flame holder on the stability of propane-air flames using the following additives: hydrogen, air, and a premixed hydrogen-air mixture. It is found that the ejection of premixed hydrogen and air substantially increases blow-off velocities in both rich and lean propane-air mixtures. The effect of the additives is attributed to the changed gas composition in a critical region adjacent to the flameholder. A method of estimating the dimensions and the effective gas composition of this critical region is presented and can be used to predict approximately the effect of additives on the basis of fundamental combustion parameters.

FURTHER STUDIES ON THE LIGHT SCATTERING TECHNIQUE FOR DETERMINATION OF SIZE DISTRIBUTIONS IN BURNING SPRAYS. I. R. A. Dobbins. Princeton U. Dept. Aero. Eng. AEL Rep. 463 (AFOSR TN 59-700), Apr. 10, 1959. 37 pp. 15 refs. Review of theoretical and experimental work in light scattering by spherical particles in which certain inconsistencies are pointed out. A revised no-multiple-scattering theory is offered which correctly predicts various limiting cases. The experimental considerations limiting the size of the particles which can be measured are discussed and it is estimated that the technique can be extended to include particles of the size formed in combustion chambers of injectors and atomizers. The possible adverse effect of scattering due to the presence of thermal gradients present in combustors is considered.

VLIIANIE PUL'SATSII POTOKA NA TURBULENTNUIU SKOROST' RASPROSTRANENIIA PLAMENI. L. S. Kozachenko. AN SSSR Otd. Tekh. Nauk Izv. Energ. i Avtom., Mar.-Apr., 1959, pp. 21-25. In Russian. Study of the mechanism of flame propagation in turbulent flow in order to determine the effect of flow pulsations. A burner is described which allows a variation of the degree of turbulence between 1.7% and 15.7%. The turbulent characteristics are measured by means of a glow-discharge anemometer and the absence of inertia in glow discharge at pulse frequency up to 20 kc./sec. is indicated. Includes presentation of some results obtained by measuring the flow pulses in various turbulence generating arrangements under the conditions of isothermal flow and combustion of homogeneous fuel-air mixtures. It is shown that the flame turbulent velocity can be represented by the sum of the normal flame propagation velocity, the mean quadratic pulsation of the isothermal flow, and the additional pulsation generated by the flame.

Heat Transfer

ON SOME PROBLEMS IN RADIATIVE HEAT TRANSFER. S. S. Abarbanel. MIT FDRG Rep. 59-1 (AFOSR TN 59-531) [AD 216538], Apr., 1959. 205 pp. 32 refs. Study of time dependent temperature distribution in radiating solids and radiative heat transfer in high-speed free molecular flow. In the first problem, solutions are found for the cases of a semi-infinite solid, a flat plate, a solid sphere, and a spherical shell. It is shown that in all cases the spatial temperature distribution can be deduced from the surface temperature through a Duhamel integral. The surface temperature problem is then formulated as a singular, nonlinear Volterra integral equation, the kernel of which depends on the particular geometry of the body in question. In the free molecular flow the cases considered are the flat plate, a solid sphere, and a thin spherical shell. When the temperature is nondimensionalized appropriately, the problem is found to possess similitude properties. Solutions for this dimensionless temperature are found in terms of a similarity parameter. The expected range of the similarity parameter in the upper atmosphere is discussed. It is shown that for this expected range the effect of radiation results in surface temperatures that are of the same order as, or smaller than, the free stream ambient temperature.

TRANSIENT HEAT TRANSFER IN LAMINAR FLOW IN THE ENTRANCE REGION OF TUBES WITH HEAT CAPACITY. V. S. Arpaci. USAF WADC TR 59-14 [AD 210479], Jan., 1959. 84 pp. 28 refs. Investigation of the transient temperatures of the fluid and the tube wall at the entrance

of circular tubes for the case of a step temperature in the inlet fluid. The principle of energy conservation for the tube-wall is considered in addition to the usual fluid continuity, momentum, and energy equations. A method of successive approximations is used to solve the fluid and tube-wall energy equations. A modified Nusselt Number is defined, whose use in the prediction of the mean temperature variations of the fluid and tube-wall uncouples the two energy equations. The theory is checked by experimental measurements, and the first approximation of the tube-wall temperature is compared with a quasi-steady theory.

HEAT TRANSFER IN DISSOCIATED COMBUSTION GASES. J. C. Cutting, J. A. Fay, W. T. Hogan, and W. C. Moffatt. MIT Dept. Mech. Eng. TR (AFOSR TR 59-78), July, 1959. 45 pp. 25 refs. Theoretical and experimental investigation to determine the rate of heat transfer from gases in detonation waves. For the experimental measurements, a wire heat transfer gage is developed and calibrated, and is used in conjunction with a rectangular shock tube through which the detonations are passed. Tests are performed using stoichiometric H_2-O_2 mixtures at various initial pressures, and also a number of C_2H_2-O_2 mixtures at an initial pressure of 1 atm. A theoretical treatment of the heat transfer rates, based on stagnation point heat transfer theory, is presented, as well as a detailed examination of the thermodynamic and transport processes taking place at the surface of the gage. The heat transfer to the coated gages is explained in terms of a non-catalytic wall effect. The total heat transfer is less than expected for the Mach and Reynolds Numbers of the experiments.

VTOL & STOL

AN ANALYSIS OF SOME VTOL TRANSITION MOTIONS. S. B. Gates and C. F. Griggs. Gt. Brit., RAE TN Aero. 2596, Nov., 1958. 54 pp. Preliminary analysis of VTOL transition motions in which the attitude, the incidence, and the inclination of the thrust are constant, so that the path is a straight line in still air and is maintained by varying only one of the two engine controls. This leads to a take off in which the aircraft rises vertically to rest and then, after a hovering pause to change the thrust inclination, accelerates horizontally to its airborne speed. The landing is essentially the same maneuver in reverse but more difficult and some correcting motions are considered. Suggestions are made for modifying the basic motions to round off the hovering corner in both take off and landing. Corrections for a horizontal wind are worked out. Fuel consumption is estimated throughout the calculations, but they cannot include the leaks occurring in any established VTOL regime.

NOTE ON THE MINIMUM POWER REQUIRED FOR FLIGHT AT LOW AIRSPEEDS. R. J. Templin. Canada, NRC Aero. Rep. LR-245, May 21, 1959. 24 pp. Analysis considering an idealized form of aircraft having a lifting wing and a jet or slipstream issuing at an angle to flight direction so as to produce lift and thrust. The power required to produce the kinetic energy of the jet is calculated for all flight speeds down to zero. For sustained level flight at any speed there is an optimum wing lift coefficient for minimum power. In some cases, the achievement of optimum lift may require circulation control. Since the idealized aircraft roughly represents a number of proposed types of VTOL and STOL aircraft, some general conclusions are possible concerning the power required by such aircraft in low-speed flight.

A WING-SUBMERGED LIFTING FAN: WIND TUNNEL INVESTIGATIONS AND ANALYSIS OF TRANSITION PERFORMANCE. R. L. Wardlaw and N. V. McEachern. Canada, NRC Aero. Rep. LR-243, Apr., 1959. 72 pp. Presentation of results of wind tunnel force measurements on a high solidity fan embedded in a two-dimensional symmetrical wing, with the fan axis normal to the wing chord plane. A discussion of results and comparison with a simple momentum theory in order to study their usefulness in VTOL project applications is included, and it is shown that, over a limited range, fan power and model force measurements provide reasonable correlation with theoretical predictions. The understanding of the flow in the vicinity of the fan is facilitated by surface pressure measurements and water tunnel flow visualization studies.

DYNAMIC STABILITY ANALYSIS OF DUCTED FAN TYPE FLYING PLATFORMS. R. N. Greenman and M. G. Gaffney. Hiller Aircraft Adv. Res. Div. Rep. ARD-233, May 29, 1959. 154 pp. Analysis of the longitudinal dynamic stability characteristics in hovering and level low-speed flight for the Hiller 7-ft.-diam. ducted fan flying platform. Several configuration variations are investigated, including duct section and chord, number of propeller blades, propeller blade setting, and clearance between propeller tips and inside of duct. Standard methods are used to develop the equations of motion, and time histories, obtained on an analog computer, as well as the resulting stability parameters are presented graphically. The present gyrobar stabilizer system provides sufficient damping in hovering flight but will not overcome the divergent motion in forward flight leading to the deterioration of dynamic characteristics with increasing speed. This is primarily due to the static instability which occurs at higher speeds.

AN INVESTIGATION OF THE FUNDAMENTAL PARAMETERS WHICH GOVERN THE AERODYNAMICS OF VARIOUS WING-PROPELLER COMBINATIONS AS RELATED TO VECTORED SLIPSTREAM AIRCRAFT. N. R. Augustine. Princeton U. Dept. Aero. Eng. Rep. 437, Oct., 1958. 214 pp. 21 refs. Study of the basic aerodynamics of wing-propeller combinations. Aspect ratio, propeller diameter, solidity, thrust axis position, and propeller plane are varied to investigate the fundamental parameters which govern the wing-propeller combination. The validity of using the slipstream dynamic pressure as a fundamental variable is considered in some detail.

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A Parametric Amplifier in Space-Probe Tracking. W. C. Pittman. *Astronautics*, Aug., 1959, pp. 40, 44. Description of the junction-diode amplifier used for tracking Pioneer IV to a distance of 20,000 miles.

Photogrammetric Flare Triangulation. Appendix A—On the Determination of Accurate Estimates of Plate Coordinate Variance Prior to Flare Triangulation. Appendix B—A Quasi Least Squares Determination of Initial Approximations for the Rigorous Adjustment. D. C. Brown. *RCA Data Red. TR 46 (AFMTC TR 59-3) [AD 211431]*, Dec. 2, 1958. 46 pp. Discussion of photogrammetric flare triangulation for geodetic purposes, based on two numerical studies. The first is based upon actual ballistic camera observation of missile-borne flares, and the other on a proposed photogrammetric net designed to determine the locations of Hawaii and Midway relative tot he North American continent.

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Studies of the Distribution of Ultraviolet Sky Radiation. IX—Ozone Absorption Layer and

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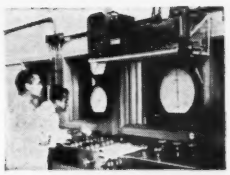

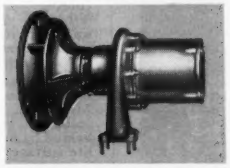

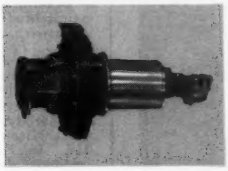

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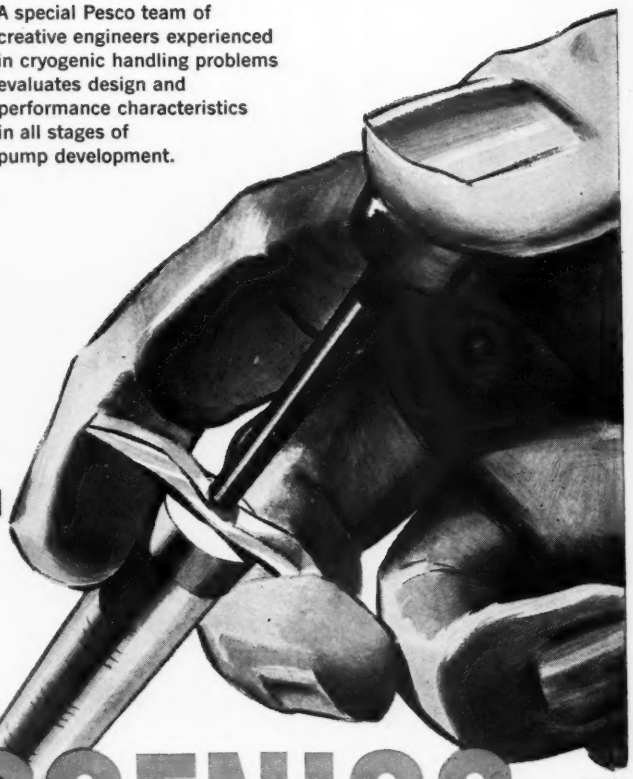

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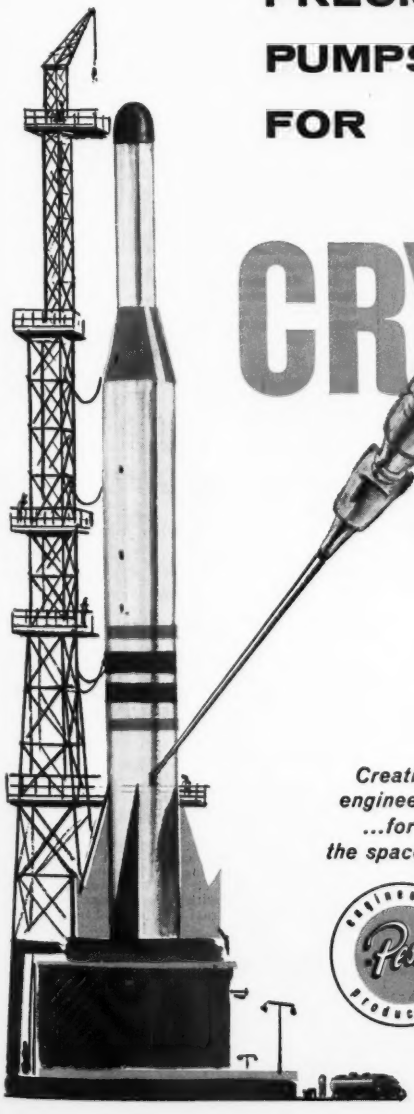

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Die Einflüsse von Kompressibilität, trapezförmiger Abwindverteilung und des Blattspitzenverlustfaktors auf Schlagkoeffizienten und Schub eines Hubschrauberrotors. Gerhard Brüning. (*DFL Inst. Flugmech., Bericht No. 101*, 1958.) *ZFW*, June, 1959, pp. 149–163. In German. Study of the effect of compressibility, trapezoidal downwash distribution, and blade tip losses on the flapping coefficient and thrust of a helicopter rotor.

Safety

Special Issue: Professional Pilot's Symposium on Air Space Safety. *Soc. Exp. Test Pilots Quart. Rev.*, Winter, 1959. 222 pp. *Partial Contents:* Making the Aircraft Easier to See. Improving Cockpit Visibility from Present and Proposed Aircraft. Insuring Vigilance from Prescribed Crew Stations. Modernization of Air Space Restricted Areas. Modernization of the Nation's Airways.

Structures

Design Aspects of Bonded Structures. O. Ljungström. *CIBA Aircraft Bul. 4*, May, 1959. 25 pp. Discussion of different types of bonded joints, loaded and stressed in a complex manner and often subjected to high temperature service for which design information is lacking.

Beams & Columns

On the Optimum Design of an I-Section Beam. S. Krishnan and K. V. Shetty. *J. Aero/Space Sci.*, Sept., 1959, pp. 599, 600. Presentation of a method for determining the optimum dimensions for an I-section beam by minimization of the weight subject to the conditions of simultaneous failure in local buckling of the compression element and by direct stress due to bending. Results are compared with those obtained by Shanley using his structural index method for a typical example.

Elasticity & Plasticity

Special Issue: Non-Homogénéité en Elasticité et Plasticité. (*IUTAM Symposium, Warsaw, Sept. 3–9, 1958.*) *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, No. 2-3, 1959, pp. 73–245. In English, French, German, and Russian. *Partial Contents:* On the Fundamentals of the Theory of Elasticity of Plane Incompressible Non-Homogeneous Media, J. Golecki. The Basic Problem

XUM

of a Non-Linear and Non-Homogeneous Half-Space. K. Hruban. La Méthode de la Fonction de Tension dans le Problème de la Torsion des Barres Anisotropes Non-Homogènes, C. I. Borş. The Energy Method of Networks of Arbitrary Shape in Problems of the Theory of Elasticity, J. Szmelter. Effects of Non-Homogeneity Caused by Strain-Hardening on the Small Deformations of a Rigid-Plastic Solid, E. T. Onat. Problems of Thermoplasticity of a Spherical Shell, M. Rogoziński. Plastic Non-Homogeneity: A Survey of Theoretical and Experimental Research, W. Olszak and W. Urbanowski. Some Problems of Creep Buckling of Homogeneous and Non-Homogeneous Bars, M. Zyczkowski. On the Statistical Mechanics of Wave Propagation in Non-Homogeneous Solid Bars, M. Z. Krzywoblocki. The Problem of Elastic-Plastic Waves in a Non-Homogeneous Bar, P. Perzyna. Stress Field and Structural Non-Homogeneity of Spherical Polymers, J. Zawadzki. An Iteration Method for the Solution of Finite Deformation Problems in Elasticity, W. R. Seugling.

Some Basic Principles in the Mechanics of Solids Without a Natural Time. R. Hill. *J. Mech. & Phys. Solids*, June, 1959, pp. 209–225. 24 refs. Presentation of equations and problems pertinent to the definition of solids in terms of tensor relations. A discussion of the criterion of uniqueness, stability, rate equations with a potential, stress-rate definitions, and elastic-plastic solids is also included.

A New Look at Ductility. M. V. Zaustin. *Mach. Des.*, July 23, 1959, pp. 134–141. Presentation of a new method for evaluating ductility based on shear resistance and cohesion of the material. The method gives quantitative data for design and makes it possible to represent ductility graphically.

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Fatigue-Crack Propagation in Aluminium-Alloy Box Beams. H. F. Hardrath, H. A. Leybold, Ch. B. Landers, and L. W. Hauschild. (*U.S., NACA TN 3856*, 1956.) *CIBA Aircraft Bul. 1*, Mar., 1957. 26 pp. Reprint.

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Distribution of Interface Stress in Plane Strain and Axial Symmetric Compression. G. T. van Rooyen and W. A. Backofen. *J. Mech. & Phys. Solids*, June, 1959, pp. 163–168. Presentation of the results of an experimental investigation of stress distribution by means of pressure-sensitive pins embedded in one plate. It is found that theory and experiment are in general agreement.

On a Cross-Elasticity Phenomenon in Symmetrically Nonhomogeneous Plates. Yehuda Stavsky. *J. Aero/Space Sci.*, Sept., 1959, p. 607.

On the Transverse Flexure of an Infinite Strip with Semicircular Notches on Both Edges. Osamu Tamate and Shunsuke Shioya. *JSME Bul.*, May, 1959, pp. 264–271. Application of the Poisson-Kirchhoff theory for thin plates to study the effect of symmetrical notches on the flexural behavior of infinite strips subjected to plain bending.

Bending of Elliptic Plates Under a Concentrated Load. Atsushi Saito, Seichi Kimura, and Tadayoshi Shimazaki. *JSME Bul.*, May, 1959, pp. 299–305. Derivation of an exact solution for the bending of clamped or simply supported elliptic plates, presented in the form of infinite series.

Buckling of a Thin Annular Plate Under Uniform Compression. Appendix—**Buckling of Rectangular Plates Uniformly Compressed in Two Perpendicular Directions with Two Opposite Edges Simply Supported.** N. Yamaki. (*J. Appl. Mech.*, June, 1958, pp. 267–273.) *Tôhoku U. Rep. Inst. High Speed Mech., Ser. B.*, vol. 10, 1959, pp. 129–147. 13 refs.

The Transverse Flexure of Uniformly Loaded and Fully Restrained Thin Isotropic Plates with Curvilinear-Edges. W. A. Bassali. *J. Mech. & Phys. Solids*, June, 1959, pp. 145–156. 19 refs. Survey of an analysis to establish exact solutions for the complex potentials and small transverse deflections of clamped elastic plates subject to uniform loading, and presentation of certain equations and diagrams relative to boundary conditions, twisting moments, and shearing forces.

Publications abstracted may be borrowed from the IAS Library. In making inquiry, please mention the month of *Aero/Space Engineering* in which the abstract appeared. This will facilitate servicing of requests.

Plates with Holes

Creep Stresses and Strains in an Axially Loaded Plate with a Hole. Joseph Marin. *Franklin Inst. J.*, July, 1959, pp. 53–60. Development of an approximate method for analyzing a plate with a circular hole subjected to tension accompanied by creep.

Sandwich Construction

Transverse Shear Stiffness for the Double "V" Corrugated-Core Sandwich Panel. A. D. Sapowith. *Aero/Space Engrg.*, Sept., 1959, pp. 53–56. Application of the principles of Libove and Hubka to predict one of the elastic constants for a corrugated-core sandwich panel. The value of this constant represents the transverse shear stiffness of the panel. Formulas and charts for the evaluation of this constant are included together with experimental data to substantiate the analysis.

Testing Methods

Photoelasticity. C. R. Smith. *Aircraft & Missiles Mfg.*, Aug., 1959, pp. 14–17. Presentation of a method for evaluating stress distribution either roughly or with quantitative precision.

From Ultrasonics a New Stress-Analysis Technique—Acoustoelasticity. R. W. Benson and V. J. Raelson. *Prod. Eng.*, July 20, 1959, pp. 56–59. Description of a technique for determining residual stresses in materials, assuming the existence of a stress-acoustic effect similar to the familiar stress-optic effect.

Measurement of High Intensity Stress Pulses. J. S. Buchanan and H. J. James. *Brit. J. Appl. Phys.*, June, 1959, pp. 290–295. 17 refs. Application of the modified form of the Hopkinson bar technique to the study of stress pulses produced in a simple explosive-metal system.

Thermal Stress

Thermal Stresses in Design. XI—Stresses Under Plastic Flow and Creep. S. S. Manson. *Mach. Des.*, July 9, 1959, pp. 124–129. 14 refs. Discussion of methods of computing stress distributions in materials where the yield point is exceeded. Plastic flow equations and stress-strain relations are developed.

Thermal Stresses in Design. XII—Plastic Stresses and Strains by Successive Approximations. S. S. Manson. *Mach. Des.*, July 23, 1959, pp. 144–150. 14 refs. Description of several ways of applying a method of successive approximations to thermal stress problems in which the starting point is (a) two unknowns or (b) temperature with a two-dimensional distribution.

Thermal Stresses in Design. XIII—Incremental Solutions for Plastic Stresses and Strains. S. S. Manson. *Mach. Des.*, Aug. 6, 1959, pp. 127–133. 16 refs. Discussion of the incremental theory of plasticity considering how and when it is applied to thermal stress problems.

Thermal Shock in an Elastic Body with a Spherical Cavity. Eli Sternberg and J. G. Chakravorty. *Quart. Appl. Math.*, July, 1959, pp. 205–218. 22 refs. ONR-sponsored analysis of the dynamic thermoelastic response of an infinite medium with a spherical cavity to a sudden uniform change in the temperature of its internal boundary. By means of the Laplace transform, a closed solution to this problem is obtained in terms of error functions of real and complex arguments.

Wings

Structural Parameters for a Metal Wing in Design Stage. B. J. Cijan. *Aero Rev.*, Jan., 1958, pp. 35–37. Discussion of design characteristics of a high aspect ratio all-metal wing of multistringer type, based on the experience with the prototype all-metal sailplane Oreo III-Meteor.

Thermodynamics

Heat Transfer

Heat and Mass Transfer Bibliography with Selected Abstracts. W. J. Christian and T. H. Schiffman. *USAF WADC TR 58-186 [AD 151199]*, May, 1958. 167 pp. 286 refs.

Radiator Areas of Thermopile Generators in Space. D. L. Kerr. *Aero/Space Engrg.*, Sept., 1959, pp. 57, 62, 66. USAF-supported investigation of the radiating surface area required to reject the waste heat from a power package located in space and evaluation of results for providing a basis for design optimization of space power packages.

VTOL & STOL

Lifting Systems for VTOL Vehicles. Scott Rethorst and W. W. Royce. (*IAS 27th Annual Meeting, New York, Jan. 26–29, 1959, Rep. 59-123.*) *Vehicle Res. Corp. Rep. 2*, May 2, 1959. 68 pp. ONR-sponsored analysis.

Die militärischen Aufgabenbereiche der STOL- und VTOL-Flugzeuge. G. W. Feuchter. *Flugwelt*, July, 1959, pp. 267–272. In German. Survey of the development of STOL- and VTOL-type aircraft for military purposes.

Water-Based Aircraft

Realistic Modeling of Waterbased Aircraft. R. H. Oversmith. *Auto. Control*, July, 1959, pp. 46–54. 10 refs. Calculations using an analog computer to determine solutions for landing and take off in both smooth and rough waters.

Cavitation Tests on Hydrofoil of Simple Form. VII—On Four Profiles of 7 and 11.7 Per Cent Thickness Ratios. VIII—On Six Profiles of 15 Per Cent Thickness Ratio. IX—On Four Profiles of 4 Per Cent Thickness Ratio. X—On Two Profiles Respectively of 7 and 3.5 Per Cent Thickness Ratios. F. Numachi, M. Nakamura, and I. Chida. *Tôhoku U. Rep. Inst. High Speed Mech., Ser. B*, vol. 10, 1959, pp. 41–128. 19 refs.

Transitional Phenomena in Ultrasonic Shock Waves Emitted by Cavitation on Hydrofoils. F. Numachi. (*ASME Annual Meeting, New York, Nov. 30-Dec. 5, 1958, Paper 58-A-117.*) *ASME Trans., Ser. D - BE*, June, 1959, pp. 153–162; Discussion, pp. 162–166. Investigation of the nature of anomalies occurring in the shock-wave spectrum and clarification of its relation to cavitation-bubble size. It is demonstrated that these anomalies can be produced in closed-circuit cavitation tunnels and in any flow subjected to preliminary cavitation at a point upstream of the point of principal cavitation.

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REVIEWS OF *Books*

. . . in the field of aeronautical engineering and space technology

AERODYNAMICS

Hypersonic Aerodynamics. Robert Wesley Truitt. New York, The Ronald Press Co., 1959. 462 pp., diagrs. $10.

The purpose of this book is to present the fundamental principles of hypersonic aerodynamics and their application to missile design problems. Emphasis has been placed on both theoretical and experimental findings and on an engineering approach to the problems of determining the aerodynamic characteristics of complete missile configurations, including certain aspects of stability and control. The text is divided into ten chapters which discuss hypersonics, two- and three-dimensional hypersonic flow, minimum-drag bodies, hypersonic small-disturbance and slender body theories, hypersonic flow over blunt bodies, complete configurations, stability and control, and real gas effects.

Professor Truitt is Head of the Aeronautical Engineering Department, Virginia Polytechnic Institute.

CHEMISTRY

Chemical Engineering Practice. Vol. 6, Fluid Systems, Part 2. Edited by Herbert W. Cremer and Trefor Davies. New York, Academic Press, Inc.; London, Butterworths Scientific Publications, 1958. 620 pp., illus., diagrs., tables. $19.50.

Contents: Gas Absorption, W. S. Norman and T. T. Hu. Operating Characteristics of Packed Absorption Columns, P. J. King. Evaporation Practice, S. B. Watkins, H. D. Macmurray, and K. G. Forker. Fluidization and Fluidized Beds, J. S. M. Botterill. Applications of Fluidization, Roy Turner. Liquefaction and Fractionation of Gases, J. B. Gardner. Adsorption, R. Worthington. Refrigeration Practice, H. W. Pasteur. Leaching, M. B. Donald. Crystallization, J. W. Mullin. Colloids, J. W. Mullin. Filtration, M. B. Donald. Selection, Sizing, and Operation of Filters, K. C. Salter and A. P. Hosking. Centrifuging, J. W. Mullin. Sublimation and Vacuum Freeze Drying, S. D. Kemp.

Some Problems of Chemical Kinetics and Reactivity, Vol. 2. N. N. Semenov. Translated from the Russian by Michel Boudart. Princeton, N.J., Princeton University Press, 1959. 331 pp., diagrs., tables. $4.50.

This volume contains the third and fourth parts of the *Kinetics of Chain Reactions* which first appeared in 1954 and also incorporates some revisions and considerable additions sent to the translator by Mr. Semenov. No attempt has been made to edit the original text or to alter its Russian flavor.

Volume 1 was annotated in the February, 1959, issue of AERO/SPACE ENGINEERING.

COMPUTERS

Programming for Digital Computers. Joachim Jeenel. New York, McGraw-Hill Book Co., Inc., 1959. 517 pp., diagrs., tables. $12.

For readers with no previous programing experience, this work provides a methodical approach to the preparation of problems for stored-program calculators. The approach is based on the representation of a program as a logical structure of standardized building blocks. This structure serves two primary purposes: to provide a conceptual framework within which the programer can create a program more rapidly and efficiently, and to permit programs for different purposes and different machines to be presented in a uniform manner. The principles and procedures presented apply to scientific and technical problems, as well as to commercial data processing, and are not restricted to specific machines, but apply to stored-program calculators in general. Topics covered include such recent developments as indirect addressing, randomized addresses, random-access storage, in-line processing, concurrent operations, and nonmachine languages.

Mr. Jeenel is a Research Associate with the Watson Scientific Computing Laboratory, Columbia University.

DIRECTORIES

Indian Skyways; Aviation Directory of Asia (Including Australia & New Zealand), 1959 Ed. Edited by R. Vaughan-Fowler. Bombay, Aeronautical Publications of India Private, Ltd., 1959. 370 pp., illus., diagrs. $3.00.

ENGINEERS & ENGINEERING

Professional Engineers' Income and Salary Survey, 1958. National Society of Professional Engineers. Washington, The Society, 1959. 51 pp., diagrs., tables. $2.00.

LUBRICATION

ASLE Transactions, Vol. 2, No. 1. Edited by John Boyd. American Society of Lubrication Engineers. New York, Pergamon Press, 1959. 157 pp., illus., diagrs., tables. $12.50.

Contents: Development of Radiation Resistant Oils, J. G. Carroll and R. O. Bolt. The Effects of High Energy Ionizing Radiation on Turbine Oil Performance Characteristics, C. F. Kottcamp, R. P. Nejak, and R. T. Kern. Viscoelastic Behavior of Greases, E. O. Forster and J. J. Kolfenbach. Development of Seals for Rocket Engine Turbopumps, J. E. Wolf and R. E. Connelly. A Study of Design Criteria for Oscillating Plain Bearings, W. A. Glaeser and C. M. Allen. Adhesion Between Metals and its Effect on Fixed and Sliding Contacts, W. P. Mason. Transition Temperatures in Sliding Systems, R. S. Fein, C. N. Rowe, and K. L. Kreuz. Wear and Friction of Filled Polytetrafluoroethylene Compositions in Liquid Nitrogen, D. W. Wisander, C. E. Maley, and R. L. Johnson. The Conduction of Current in Bearings, H. N. Kaufman and J. Boyd. A Surface Effect Associated with the Use of Oils Containing Zinc Dialkyl Dithiophosphate, P. A. Bennett. Film Formation by and Antiwear Additive in an Automobile Engine, M. J. Furey. Testing and Operation of Ball Bearings Submerged in Liquefied Gases, K. B. Martin and R. B. Jacobs. Effect of Fiber Orientation, Temperature and Dry Powder Lubricants on Rolling Contact Fatigue, W. J. Anderson and T. L. Carter. Rolling Contact Fatigue Evaluation of Bearing Materials and Lubricants, E. G. Jackson. Materials in Rolling Element Bearings for Normal and Elevated (450°F) Temperature, T. W. Morrison, H. O. Walp, and R. P. Remorenko. A Theoretical Study of the Effect of Offset Loads on the Performance of a 120° Partial Journal Bearing, A. A. Raimondi.

MANPOWER

Scientific Manpower and Education; Hearings Before the Committee on Science and Astronautics, U.S. House of Representatives, 86th Congress, 1st Session, Feb. 25, March 12–13, May 5, 18, 19, 20, 22, and 26, 1959. Washington, Superintendent of Documents, 1959. 708 pp., diagrs., tables.

MATERIALS

Proceedings of the American Society for Testing Materials, Vol. 58, 1959; Committee Reports, Technical Papers. Philadelphia, The Society, 1959. 1420 pp., illus., diagrs., tables. $12.00.

The *Proceedings* include all accepted reports and papers offered to the Society during the current year, with discussion. The table of contents and subject and author indexes cover all papers and reports published by the Society during the current year, which, in addition to those appearing in the *Proceedings*, include those accepted for publication in the ASTM *Bulletin* or in *Special Technical Publications*.

MATHEMATICS

A Table of the Incomplete Elliptic Integral of the Third Kind. R. G. Selfridge and J. E. Maxfield. (Released Within the Department of Defense as NAVORD Report 5643, NOTS 1870.) New York, Dover Publications, Inc. 805 pp., tables. $7.50.

The table was originally computed to solve the specific problem of surface areas of geometric bodies which can be expressed only in terms of the incomplete elliptic integral of the third and lower kinds. It is expected to be of special use to those working in the fields of fluid dynamics, heat flow, and related topics. The integral also appears in the solution of problems of magnetic potentials due to a circular current, the motion of a spherical pendulum, and in certain kinds of seismological work. Calculations were made on an IBM Type 704 Calculator and were verified by means of a check integral at the completion of each value of alpha.

Both authors are with the Research Department, U.S. Naval Ordnance Test Station.

PHYSICS

Recent Research in Molecular Beams: A Collection of Papers Dedicated to Otto Stern, On the Occasion of His Seventieth Birthday. Edited by Immanuel Estermann. New York, Academic Press, Inc., 1959. 190 pp., diagrs., tables. $6.50.

Contents: Molecular Beam Research in Hamburg, 1922–33, I. Estermann. Molecular and Atomic Beams at Berkeley, W. A. Nierenberg. Velocity Distributions in Potassium Molecular Beams, P. M. Marcus and J. H. McFee. Electron Magnetic Moment and Atomic Magnetism, V. W. Hughes. Hyperfine Structure Measurements in the Metastable 2S State of Hydrogenic Atoms, P. Kusch. Shapes of Molecular Beam Resonances, N. F. Ramsey. Comparison of Methods for the Determination of Nuclear Spin as Applied to Radioactive Nuclei, V. W. Cohen. Molecular Scattering at the Solid Surface, F. C. Hurlbut. Some Applications of Molecular Beam Techniques to Chemistry, S. Datz and E. H. Taylor. A Stern-Gerlach Experiment on Polarized Neutrons, J. E. Sherwood, T. E. Stephenson, and S. Bernstein.

Absorption and Dispersion of Ultrasonic Waves. Karl F. Herzfeld and Theodore A. Litovitz. New York, Academic Press, Inc., 1959. 535 pp., diagrs., tables. $14.50.

Contents: General Theory of Relaxation in Fluids: The Stokes-Navier Equations of Hydrodynamics. General Considerations on Relaxation. Special Topics. Gases: Application of the General Formulas to Gases. Experimental Methods to Determine Velocity and Absorption of Ultrasonic Waves in Gases. Experimental Results in Molecules Without Electronic Excitation. Theory of Vibrational and Rotational Energy Exchange. Liquids: General Review of Ultrasonic Absorption and Dispersion in Liquids. Experimental Methods to Determine Dispersion and Absorption of Ultrasonic Waves in Liquids. Review of Theories of Liquids. Kneser Liquids. Associated Liquids and Liquids With High Viscosity.

POWER PLANTS

Jets and Rockets. A. Barker, T. R. F. Nonweilwer, and R. Smelt. London, Chapman & Hall, Ltd., 1959. 268 pp., illus., diagrs., tables. 35s.

Several acknowledged experts have contributed to this work on methods of aircraft propulsion with the emphasis on various aspects of high-speed aerodynamics. The 18 chapters are well illustrated and include discussions on the momentum theory of jet and rocket propulsion, the rocket motor, performance calculations, jet propulsion, air resistance and aerodynamic design at high speeds, engine performance, and the performance of rocket projectiles.

RESEARCH

Space/Aeronautics Research and Development Hand Book, 1959–1960. New York, Conover-Mast Publications, Inc., 1959. 470 pp., illus., diagrs., tables. $2.00.

The *Hand Book* presents a worldwide report on the highlights and trends of research and development in the field of aviation and astronautics. The major areas covered by these reports are systems engineering, dynamics and structures, propulsion, systems and components of space/aero electronics, accessory systems and components, materials production engineering, testing and data processing, human factors, and ground support.

STRUCTURES

Proceedings of the Society for Experimenlta Stress Analysis, Vol. 26, No. 2. Edited by C. V. Mahlmann and W. M. Murray. Cambridge, Mass., The Society, 1959. 165 pp. illus., diagrs. $6.00.

Contents: A Three-Dimensional Photoelastic Investigation of the Stress Distribution in an Axially Thick Ring, M. M. Frocht and R. A. Thomson. The Use of Digital Computers in the Photoelastic Solution of the General Space Problem by the Shear-Difference Method, R. A. Thomson. Impact Loading of Structures Using Double Acting Bombs, D. A. Stuart and A. L.

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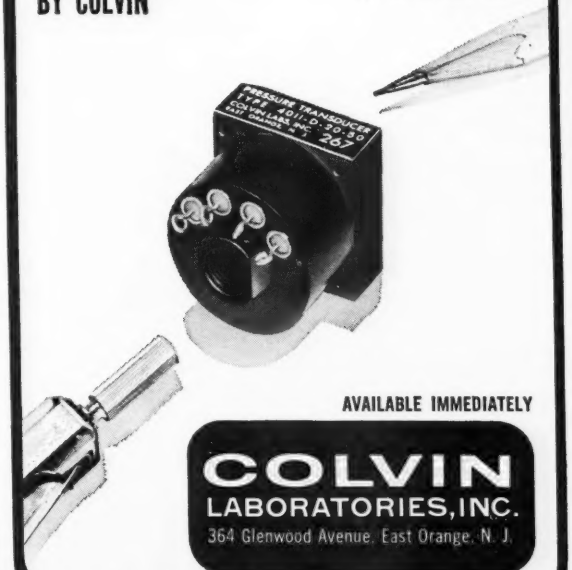

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THERMODYNAMICS

Seventh Symposium (International) on Combustion; At London and Oxford, August 28–September 3, 1958. Published for the Combustion Institute. London, Butterworths Scientific Publications; New York, Academic Press, Inc., 1958. 959 pp., illus., diagrs., tables. $35.

Contents: Part I. Mechanism of Combustion Reactions: Reactions of Hydrogen Atoms with Oxygen, B. deB. Darwent and V. J. Krasnansky. The Slow Reaction and Second Limit of the Hydrogen-Oxygen Reaction in Boric Acid Coated Vessels, R. R. Baldwin and L. Mayor. The Mercury Photosensitized Hydrogen-Oxygen Reaction at Low Oxygen Concentrations, J. S. Watson. Production of Hydrogen Peroxide in Reacting Mixtures of Hydrogen and Oxygen, J. W. Linnett and C. P. Tootal. The Rate and Mechanism of the Thermal Dissociation of Oxygen, K. F. Herzfeld. On Some Reactions Occurring During the Explosion Induction Period, V. V. Voevodsky. Reactions of Some Radicals and Their Concentration in Flames, V. N. Kondratiev. Further Studies of Induction Periods in Mixtures of H_2, O_2 and NO_2, P. G. Ashmore and B. P. Levitt. Reactions of Atomic Oxygen and Atomic Nitrogen with Oxides of Nitrogen, F. Kaufman and J. Kelso. Effect of Oxygen on Thermal Decomposition of Nitric Oxide at High Temperatures, F. Kaufman and L. J. Decker. Recent Studies of the Oxidation and Decomposition Flames of Hydrazine, P. Gray and J. C. Lee. Mechanism Involved in the Photochemically Initiated Combustion of H_2S, A. P. Zeelenberg. First Limit Induction Time Studies of CS_2-O_2 Explosions, F. R. Taylor and A. L. Myerson. A Study of Vibrational Relaxation in Carbon Monoxide by Shock Waves and Infra-red Emission, M. Windsor, N. Davidson, and R. Taylor. On the Perturbation of the Vibrational Equilibrium Distribution of Reactant Molecules by Chemical Reactions, K. E. Shuler. On the Analysis of Re-combination Reactions in an Expanding Gas Stream, F. T. Smith. Shock Tube Studies of Reaction Kinetics of Aliphatic Hydrocarbons, H. S. Glick. The Point of Attack in Hydrocarbon Oxidation—I. Propane, R. Burt, C. F. Cullis, R. Larsen, and G. J. Minkoff. Products of Cool Flame Oxidation of Propane-2-^{14}C, R. E. Ferguson and C. R. Yokley. Some Problems of Elementary Reactions in Gas-Phase Slow Combustion, Z. G. Szabó. Rate Constants of Elementary Reactions in Hydrocarbon Oxidation—Low Temperature Oxidation of Lower Hydrocarbons, J. H. Knox. Rate Constants of Elementary Reactions in Hydrocarbon Oxidation—Competitive Oxidation of Lower Hydrocarbons, J. H. Knox, R. F. Smith, and A. F. Trotman-Dickenson. Application of Radioactive Isotopes to Study the Mechanism of Some Oxidation Processes, D. Gál, F. Dutka, L. Guczi, and I. Kende. Some Processes in Gaseous Slow Combustions. Formation of Carbon Monoxide and Carbon Dioxide, G. Skirrow and C. F. H. Tipper. On High-Temperature Oxidation of Methane, G. I. Kozlov. A Mass Spectrometric Investigation of the Methane-Oxygen Reaction at Low Pressures, D. J. Fabian and W. A. Bryce. Kinetics and Mechanism of Methane Oxidation, N. S. Enikolopyan. Inhibition of Diethyl Ether-Oxygen Flames by Aliphatic Amines, D. J. Waddington. Stabilization by Aliphatic Amines of Free Radicals in Oxidation Systems, C. F. Cullis and B. A. Khokhar. Mechanism of Combustion Inhibition by Compounds Containing Halogen, W. A. Rosser, H. Wise, and J. Miller. Effects of Surfaces on Combustion of Methane and Mode of Action of Antiknocks Containing Metals, D. E. Cheaney, D. A. Davies, A. Davis, D. E. Hoare, J. Protheroe, and A. D. Walsh.

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IAS Section News *(Continued from page 23)*

vehicle for emergencies. In addition, a fixed facility was used to handle the reactor; when not mounted in the NTA, the ASTR was handled remotely in an underground pit. The aircraft was first located over the pit and the reactor then installed in or removed from the aft bomb bay by a remotely operated elevator. Such an operation required delicate sensing devices to assure alignment, which was often beset by movement induced in the aircraft by the wind.

Shielding, radiation effects, and ground support equipment must be considered in nuclear aircraft design. Convair has arrived at the following conclusions for the designer: (1) Optimize the divided shield distribution to account for performance, maintainability, and radiation damage, as well as least weight.

(2) Minimize "activatable" material on the airframe to reduce radiation environment during ground operations.

(3) Place critical materials and systems in the airplane as far from the reactor as possible.

(4) Design around offending materials by substitution.

(5) Locate critical components for easy accessibility.

Texas Section

Report on June-July Meetings

Convair—Fort Worth's manufacturing R&D activities from explosive forming to everyday production problems were discussed by **E. W. Feddersen**, Chief of Manufacturing R&D, Convair—Fort Worth, in a talk at the July 22 Specialist Meeting.

▶ Speaker at the June 26 dinner meeting was **Dr. Archie M. Kahan,** Executive Director of the Texas A&M Research Foundation, who discussed **"The Tornado —Its Care and Feeding."** He said tornados rarely have the very high winds —up to 500 m.ph.h.—attributed to them, and showed a film of the deadly twister that hit Dallas on April 2, 1957. He stated that all of the damage could have been done by winds of 150 m.p.h. with one exception. Dr. Kahan also showed a number of slides and pointed out characteristics of radar reflections of tornado clouds.

▶ Sixty members and guests toured the Chance Vought high-speed wind-tunnel facilities on June 20. CVA engineers conducted small groups through the various rooms which make up the complete facility. Explained in detail, although neither was operated, were both the 4 ft. by 4 ft. Mach 5 flexible wall tunnel and the Mach 20 hotshot tunnel.

Vernon A. Lee, *Secretary*

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921. R&D Administration—Air Force Colonel planning retirement before January 1, 1960, wants responsible position with research, educational or manufacturing organization where ability to program and manage material, financial, and manpower resources is required. Experience includes civilian aviation, manufacturing and business activities, in addition to military R&D administration, logistics, and comptroller duties.

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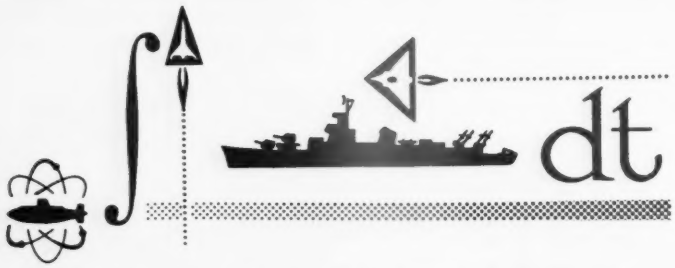

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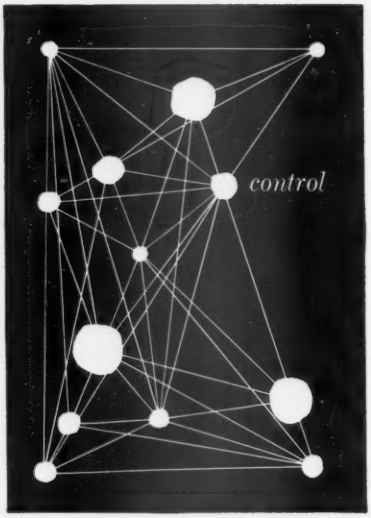

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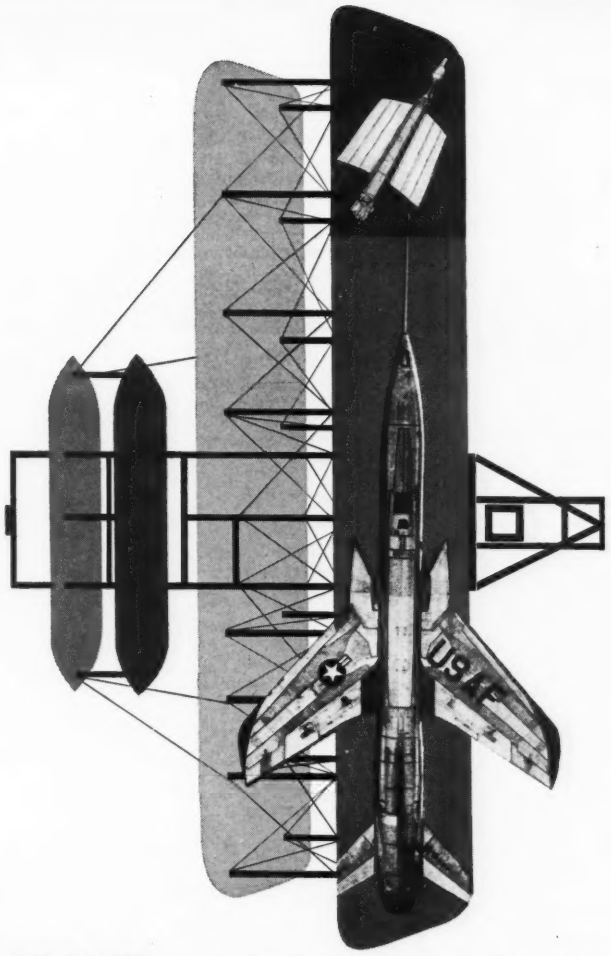

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